Wireless LANs

Agenda

- Introduction to wireless home networking
- Wireless LAN technology
- Consortiums
- IEEE 802.11
- HiperLAN & HiperLAN2
- Products & solutions available in the industry today
- Xilinx solutions in wireless LAN products
- Summary

Introduction

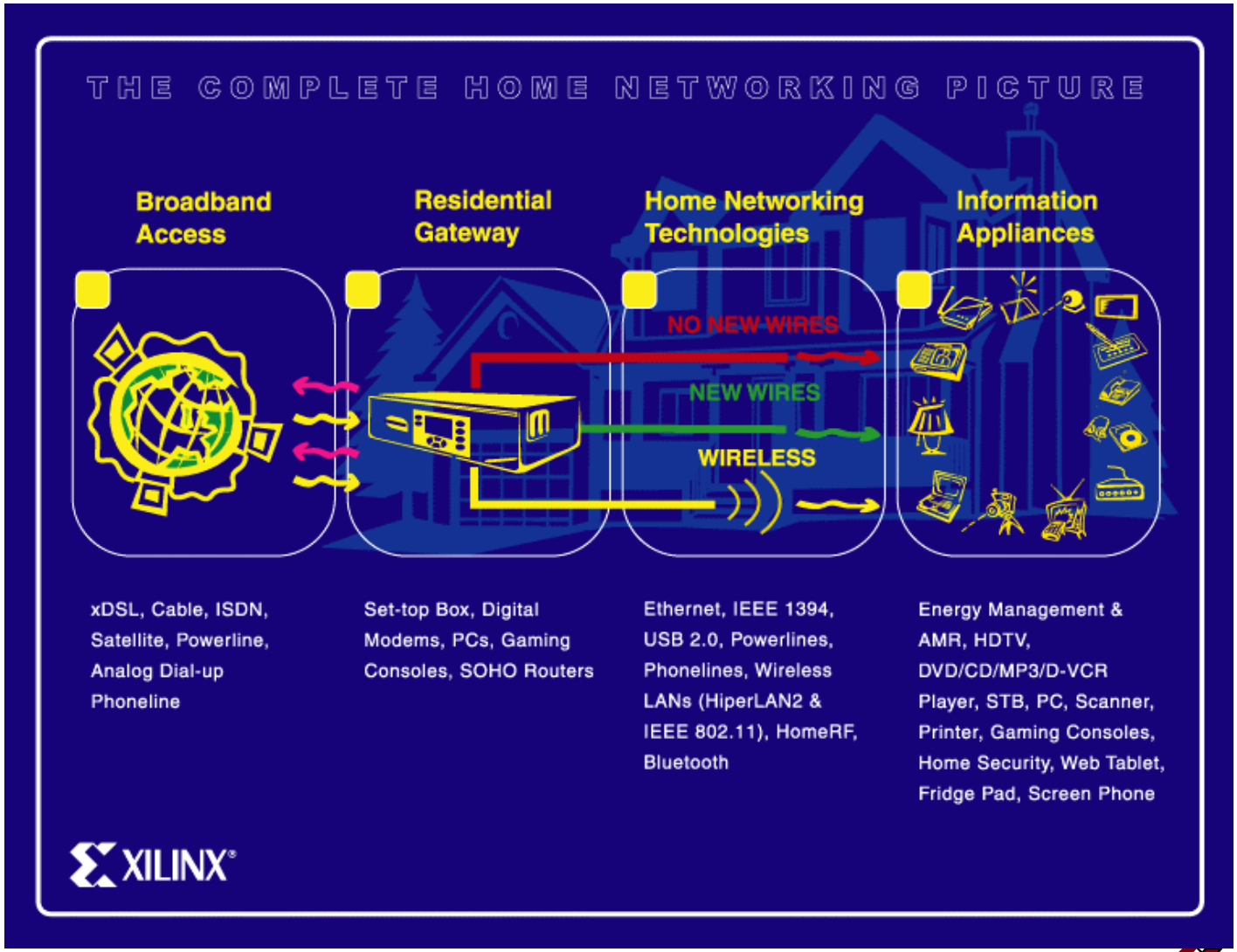
The Coming of the Digital Age

Market Trends - Wireless Home Networking

Introducing Wireless LANs

Applications for Wireless LANs

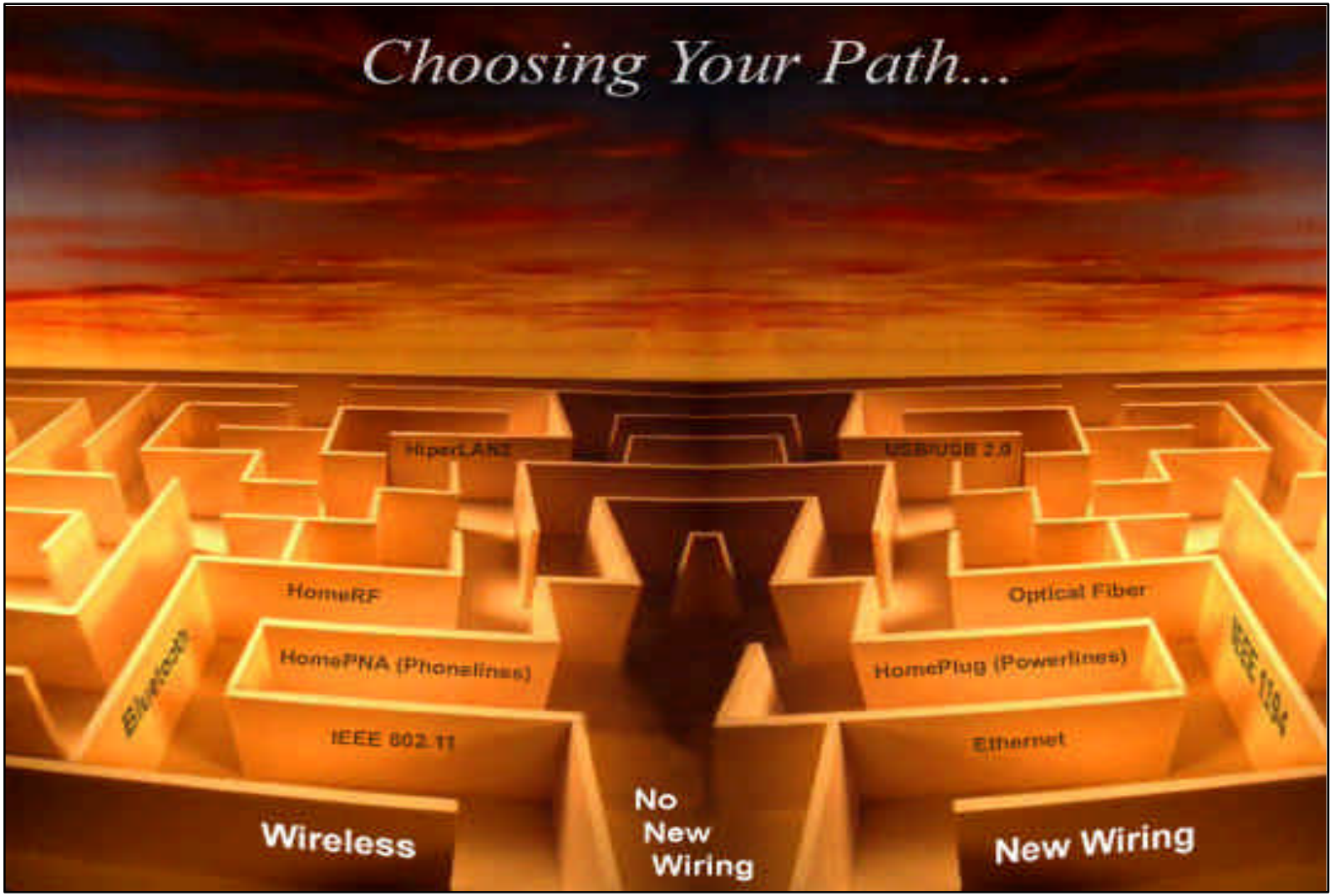
Four Aspects to Home Networking



Market Requirements and Solutions Available

	Market Requirements	Solutions Available
Broadband Access	High Speed Access for Data, Voice and Video, Always on, Simultaneous Up-link &Down-link Communication, Support Simultaneous and Multi-User Access	xDSL, Cable, Powerline, Satellite, Mobile/Wireless
Residential Gateway	Provides Access into the Home, Remote Management Access Platform, Bridging between Different Networks, Firewall and Security, E-Services Capabilities	Open System Gateway initiative (OSGI), Jini, UPnP, HAVi, DVI
Home Networking Technologies	Low Cost, Speed, Mobility, Quality of Service, Security, Reliability, Ubiquity, Ease of Use	No new wires (Phonelines, Powerlines), New wires (Ethernet, 1394, USB2.0, Optic Fiber), Wireless (HomeRF, Bluetooth, Wireless LAN)
Information Application Networks	Digital electronics with advanced computational capabilities that add more value and convenience when networked	Digital TV, HDTV, set-top box, internet screen phones, digital VCR, gaming consoles, MP3 players, cordless phones, security systems, utility meters, PCs, web pads & terminals, PDAs, digital cameras, auto PCs etc.

Home Networking Technologies



Different Strokes for Different Folks

	Home Automation	Entertainment	Information	Personal Communications	Communication
Devices	- Home appliances - Security/safety systems - Utility meters	- TV sets - Set-top boxes - DVD Players - Game consoles - VCRs - MP3 Players	- PCs - Screen phones - Printers - Modems - Routers - Hubs - Scanners	- Mobile phones - Smart phones - Handheld - Laptop - Pagers	- Corded/Cordless telephones - Fax machines
Content	Information on home processes, house environment, remote diagnostics and technical support	Rich multimedia content, electronic programming guides, impulse purchases	Discrete information on external world, shopping for household goods	Information used on the move or requiring instant action: travel, weather, local services, stock market	Information on how to reach people in time and space
Usage Pattern	Communal	Communal	Individual Shared	Individual Personal	Communal or Individual Shared
Connection to Outside World	- Power line - POTS	- Cable - DBS	- Cable modem - ADSL - POTS, ISDN	- GSM - Infrared	- POTS
Practical Networking Technology	- CEBus - X-10 - LONWorks	- IEEE 1394 (Fire Wire)	- HomeRF - HomePNA - Ethernet	- Infrared - Bluetooth	- POTS - DECT - 900MHz, 2.4GHz

Home appliances have different content, functionality, applications, and require different interconnection technologies

The Coming of Wireless Home Networking

- Home networking solutions demand
  - No new additional wires or phone jacks
  - Interoperability
    - Compliment phoneline-based home network solutions
  - Convenience
    - Simple to install
    - Easy-to-use
  - Economical: Low cost
  - Performance
    - Bandwidth to support common home networking applications
  - Secure
  - Big industry & consortium support (Bluetooth, IEEE, H2GF)

Why Go Wireless?

- Provide core home networking capabilities
  - Multiple PC users share Internet access, printers, files, drives & participate in multi-player games
  - Internet access - anywhere in & around the home
- Share wireless voice & data
- Review incoming messages
- Activate other home electronic systems by voice
- Needed in countries where phone lines cannot be used

Key Drivers: Portability & "No New Wires"

Wireless Home Networking Solutions - Pros & Cons

- Pros
  - Flexibility & mobility
  - Broad geography support at specific frequency
  - Can compliment a wired network with bridging
- Cons
  - Relatively expensive
  - Distance limits & wall attenuation (150ft barrier)
  - Security must be addressed
  - Performance
    - Prone to narrowband interference

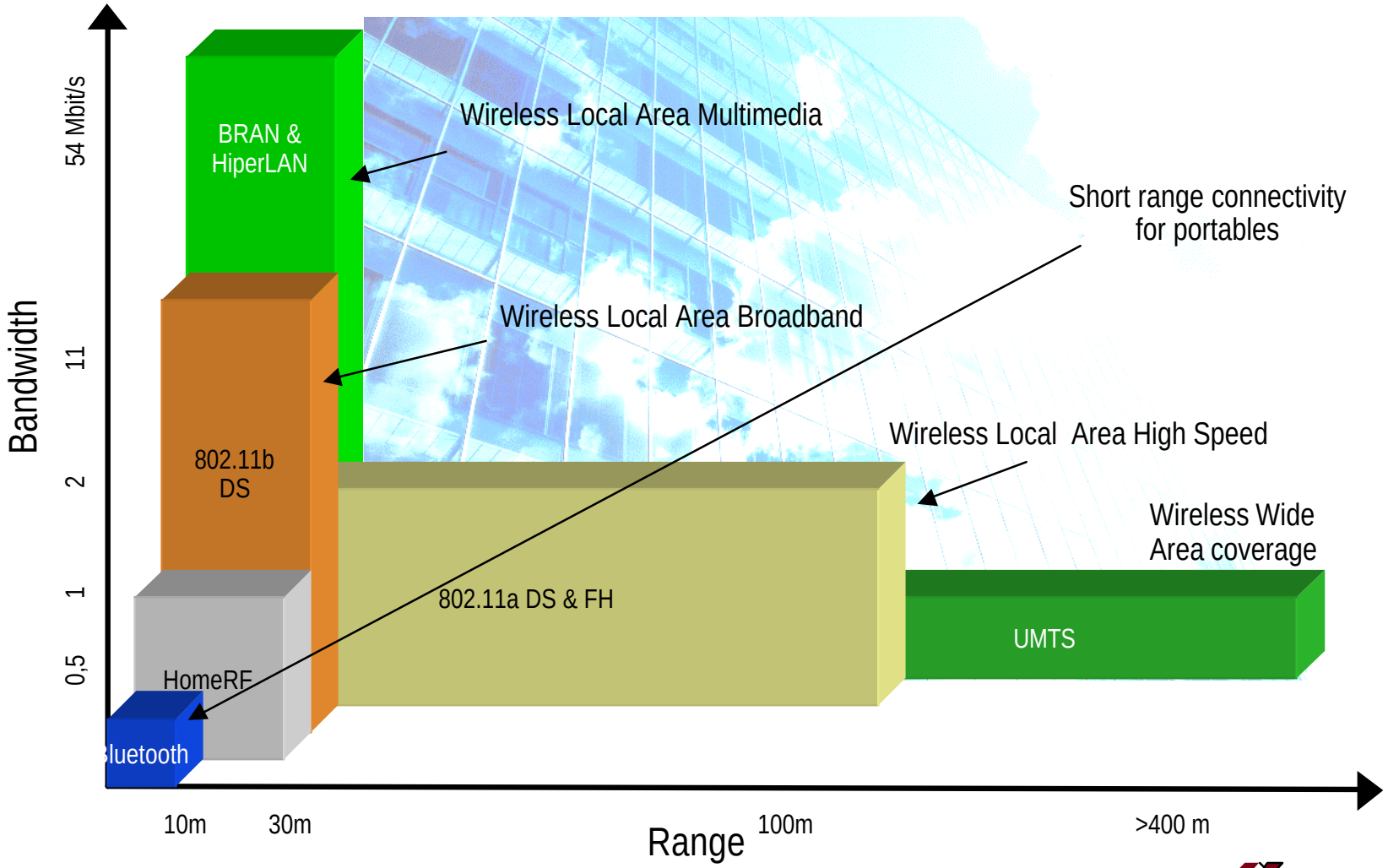
What is a Good Wireless Home Networking Solution?

- Powerful
  - Similar capabilities of a typical office network
  - Simultaneous sharing of Internet/broadband access, files & drive, printer/scanner
- Simple
  - Simple installation
  - Easy and intuitive use of network
- Economical

Wireless Home Networking Technologies

- Bluetooth & IEEE 802.15
  - Personal area networking for data & voice communications
- HomeRF
  - Home based data & voice transmissions
- Wireless LANs (local area networks)
  - High-speed wireless connectivity augmenting wired networks
  - IEEE 802.11 (a & b variations)
    - a - 5GHz standard based on OFDM
    - b - 2.4GHz standard based on Ethernet
  - HiperLAN & HiperLAN2
    - 5GHz standard based on OFDM

Wireless Technologies in Home Networking



Cutting the Wires

Technology	Physical Layer	Media Access Control Method	Raw Physical-Layer throughput (Mbits/sec)	Product Availability
IEEE 802.11	Frequency Hopping Spread Spectrum (FHSS) or Direct Sequence Spread Spectrum (DSSS)	Carrier Sense Multiple Access/Collision Avoidance (CSMA/CA)	1 or 2	Now
IEEE 802.11b	Complimentary code keying DSSS	CSMA/CA	11	Now
IEEE 802.11a	Orthogonal Frequency Division Multiplexing (OFMD)	CSMA/CA	54	2001
HiperLAN1	Gaussian Minimum Shift Keying (GMSK)	Three-phase priority driven	23.5	2000
HiperLAN2	OFMD	Cenetral resource control, Time Division Multiple Access (TDMA)	54	2001
OpenAir	FHSS	CSMA/CA	1.6	Now
Wideband OpenAir	FHSS	CSMA/CA	10	2000
HomeRF	FHSS	CSMA/CA	1	Now
Wideband HomeRF	FHSS	CSMA/CA	10	2000
Bluetooth	FHSS	Cenetral resource control, TDMA	1	2000

Variety of Technologies in the Wireless Connectivity Market

Introducing Wireless LANs

Wireless LANs Provide...

- Flexible data communication systems
  - Implemented as an extension to the wired networks (LAN)
    - Reliance on networking in business & meteoric growth of the Internet & online services are strong testimonies to the benefits of shared data & shared resources
  - Minimizes the need for wired connections
    - Users can access shared information without looking for a place to plug in
    - Network managers can set up or augment networks without installing or moving wires
- Electromagnetic waves (radio or infrared) are used to transmit & receive data over the air

Wireless LANs Are Quickly Gaining Popularity

- Combines data connectivity with user mobility
  - Provides general purpose connectivity alternative for a broad range of business customers
- Strong popularity in vertical markets
  - Health-care, retail, manufacturing, warehousing, academia
  - Productivity gains are realized by using hand-held terminals & notebook PCs to transmit real-time information to centralized hosts for processing
- Worldwide wireless LAN market
  - More than $2 billion revenues by year 2000 *
  - $2 billion WLAN annual revenues by year 2002 **

Source: * Business Research Group, ** - HiperLAN2 Global Forum

LANScape
Wireless LAN Market Drivers

- Product pricing
  - Low product prices make wireless LANs a more cost-effective proposition
  - Adapters for office products are as low as $200 & half of that for home versions
    - Apple's IEEE 802.11b card lists for $99
- Standards
  - Official or industry consortiums are driving the market
- Large networking giants
  - Industry leaders like Cisco Systems, Nortel Networks, Nokia & Ericsson are all in the game

LANScape
Wireless LAN Market Drivers

- Telecommuters
- Home use
  - Sharing peripherals & broadband access/Internet are the killer applications
- Increasing number of users are standardizing on laptops as their only computer
  - Makes mobile connectivity highly desirable
- Millions of cell phones will soon become Internet-enabled
  - Users will want to link up to laptops, hands-free kits in cars & LAN access points

Differences Between WLANs & Other Wireless Technologies

	Wireless Local Area Network (WLAN)	LAN-LAN Bridge	Wireless Wide Area Network (WWAN)	Wireless Metropolitan Area Network (WMAN)	Wireless Personal Area Network (WPAN)
Coverage Area	In building or campus	Building to building	National	Metropolitan Area	A few feet
Function	Extension or Alternate to Wired LAN	Alternate to Wired Connection	Extension of LAN	Extension of Wired LAN	Alternate to Cable
User Fee	No	No	Yes	Yes	No
Typical Throughput	1-11Mbps	2-100Mbps	1-32Kbps	10-100Kbps	0.1-4Mbps

Wireless Home Networking Technology Comparison

- Wireless LAN, HomeRF & Bluetooth technologies vary in data rate, range, frequency & marketplace aimed for

Technology		Standards Body /Proponent	PHY Layer	Data Rate	Range (meters)	Frequency (GHz)	Technology Aimed For
Wireless LAN	IEEE 802.11a	IEEE	OFDM	40	TBD	5	Office Environments
	IEEE 802.11b	IEEE	DSSS	11	100	2.4	
	HiperLAN2	HiperLAN2 Global Forum	OFDM	54	150	5	
HomeRF	SWAP 1.1	HomeRF Working Group	FHSS	1.6	50	2.4	Home Space
	HomeRF (next generation)	HomeRF Working Group	FHSS	10	50	2.4	
Bluetooth	IEEE 802.15 (Bluetooth)	Bluetooth SIG	FHSS	1	10	2.4	Consumer, short-range wireless personal area network communication
	IEEE 802.15 (high-rate)	Bluetooth SIG	FHSS	2+	TBD	2.4/5	

DSSS- Direct Sequence Spread Spectrum, FHSS - Frequency Hopping Spread Spectrum, OFDM - Orthogonal Frequency Division Multiplexing

WLANs in the Real World

- Frequently augment rather than replace wired networks
  - Provide the final few meters of connectivity between a wired network (LAN) & the mobile user
- Wireless LANs provide productivity, convenience & cost advantages over traditional wired networks
  - Mobility improves productivity & service
  - Installation speed & simplicity
  - Installation flexibility
  - Reduced cost-of-ownership
  - Scalability

Real-Life Applications of WLANs

- Increased productivity for doctors & nurses in hospitals
  - Patient information can be delivered instantly using hand-held devices or notebook PCs with WLAN capability
- Consulting and/or audit teams
  - Consulting, accounting audit teams and/or small workgroups increase productivity with quick network setup
- Library for reference
  - Students holding class on a campus greensward access the Internet to consult the catalog of the Library of Congress

Real-Life Applications of WLANs

- Information technology/network management
  - Network managers in dynamic environments minimize the overhead caused by moves, extensions to networks & other changes with WLANs
  - Network managers installing networked computers in older buildings find that WLANs are a cost-effective network infrastructure solution
  - Trade show & branch office workers minimize setup requirements by installing pre-configured WLANs needing no local MIS support
  - Network managers implement WLANs to provide backup for mission-critical applications running on wired networks

Real-Life Applications of WLANs

- Training sites
  - Employees at corporations & students at universities use wireless connectivity for easy information access, information exchanges and learning
- Industrial parks, industries and factories
  - Warehouse workers use WLANs to exchange information with central databases, thereby increasing productivity
- Critical decision making
  - Senior executives in meetings make quicker & better decisions because they have real-time information at their fingertips

Challenges and Constraints

- Frequency allocation
  - Wireless networks require that all users operate on a common frequency band
  - Frequency bands for particular uses are allocated & licensed in each country
- Reliability of the communications channel
  - Measured in average BER - bit error rate
    - Packetized voice cannot have packet loss rates in excess of order of 10^{-2}
    - For uncoded data, a BER of 10^{-5} is regarded acceptable
  - Automated repeat request (ARQ) and forward error correction (FEC) are used to increase reliability

Challenges and Constraints

- Security
  - Wired networks can have a physically secure transmission medium
    - Access to the network is easily controlled
  - Wireless network is more difficult to secure
    - Since the transmission medium is open to anyone within the geographical range of a transmitter
  - Data privacy is accomplished over a radio medium using encryption & authentication
    - Encryption comes at increased cost and decreased performance

Challenges and Constraints

- Security - Encryption
  - Intended to provide a level of security comparable to that of a wired LAN
  - In IEEE 802.11 the Wired Equivalent Privacy (WEP) feature uses the RC4 PRNG algorithm from RSA Data Security
  - The WEP algorithm was intended to be
    - Reasonably strong
    - Self-synchronizing
    - Computationally efficient
    - Exportable
    - Optional
  - Encryption comes at increased cost & decreased performance

Challenges and Constraints

- Security - Authentication
  - Means by which one station is verified to have authorization to communicate with a second station in a given coverage area
  - In the infrastructure mode, authentication is established between an access point (AP) and each station
  - Can be either Open System or Shared Key
    - In an Open System, any STA may request authentication
      - The STA receiving the request may grant authentication to any request, or only those from stations on a user-defined list
    - In a Shared Key system, only stations which possess a secret encrypted key can be authenticated
      - Shared Key authentication is available only to systems having the optional encryption capability

Challenges and Constraints

- Interference
  - Interference in wireless communications may be caused by simultaneous transmissions, i.e., collisions, by 2 or more resources sharing the same frequency band
    - Collisions are typically the result of multiple stations waiting for the channel to become idle and then begin transmission at the same time - CSMA/CD technique
    - Collisions are also caused by the hidden terminal problem
      - Where a station believing that the channel is idle begins transmission without successfully detecting the presence of a transmission already in progress
  - Interference is also caused by multipath fading
    - Characterized by random amplitude and phase fluctuations at the receiver

Challenges and Constraints

- Throughput
  - WLANs are currently targeted at data rates between 1-40 Mbps
    - Physical limitations & limited available bandwidth do not allow the capacity of WLANs to approach that of wired LANs as they ideally should
    - To support multiple transmissions simultaneously spread spectrum techniques are employed

Challenges and Constraints

- Power consumption
  - Wireless devices are portable and meant to be portable and/or mobile and are typically battery powered
    - Devices connected to a wired network are powered by the local 110V commercial power provided in a building
  - Very energy efficient devices must be designed
    - Sleep modes, low-power displays are a must
  - Timing beacons plays an important role in power management
    - All station clocks within a BSS are synchronized by periodic transmissions of time stamped beacons
      - Synchronization is maintained to within 4uSec plus propagation delay
    - 2 defined power saving modes: awake & sleep

Challenges and Constraints

- Human safety
  - Networks should be designed to minimize the power transmitted by network devices
    - Ongoing research has to confirm whether RF transmissions from radio and cellular phones are linked to human illness
    - Infrared WLAN systems optical transmitters must be designed to prevent vision impairment
- Mobility
  - System designs must accommodate handoff between transmission boundaries & route traffic to mobile users
    - While wired networks are static the primary advantage of WLANs is freedom of mobility

Customer Considerations for WLANs

- Range & coverage
- Throughput
- Integrity & reliability
- Compatibility with the existing network
- Interoperability of wireless devices
- Interference & coexistence
- Licensing issues
- Simplicity/Ease of use
- Security
- Cost
- Scalability
- Battery life for mobile platforms
- Safety

Agenda

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WLAN Standard Technology

Requirements - Applications, Service, Deployment

Functionality

PHY Layer

Data Link Layer

XILINX®

Requirements - Applications

- Data communication applications
  - Bandwidth! Always, the more the better
  - Statistical multiplexing supported
  - Minimize connection setup time
  - Minimize retransmissions
- New applications
  - Interactive applications need QoS
  - Bandwidth! Always, the more the better
  - Must work & coexist with datacom applications
  - Minimize connection setup time

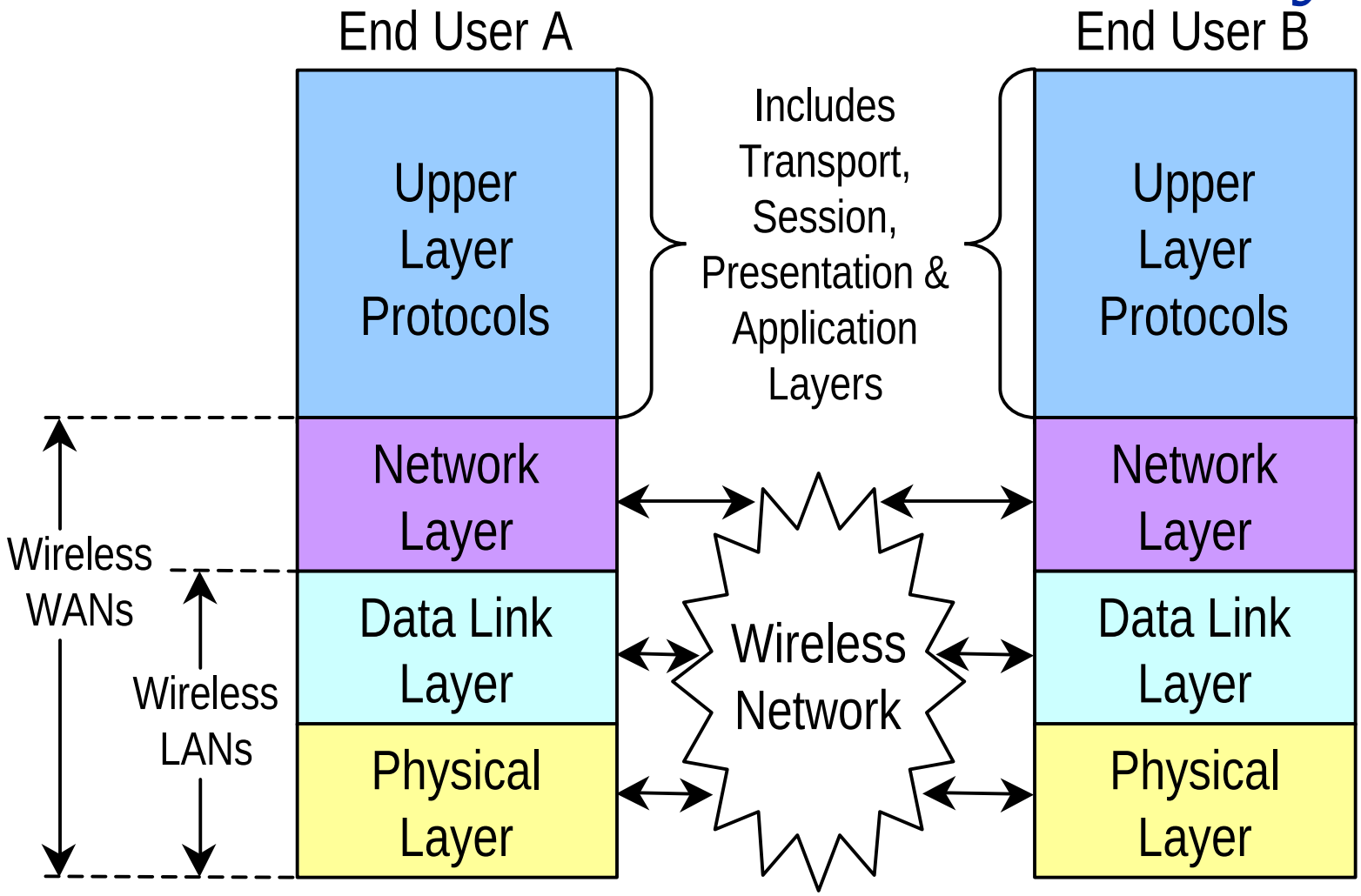
Requirements - Service

- Mobility implies service negotiation
  - Authentication
  - Operator identification, roaming
  - Bearer capabilities
- Wireless & Internet imply security
- New applications & new devices would benefit if interoperation with WAN is supported
- Interoperable products

Requirements - Deployment

- Easy to install & operate
  - Especially in indoor environments
- Scalable in cost & performance with respect to coverage & number of users
- Transparent or flexible in how to connect to fixed network & higher layers
- Available on all markets

Wireless LANs Functionality



Wireless LANs & MANs fulfil Data Link & Physical Layer functionality while wireless WANs also include functions at the Network Layer

Defining the Different Layers

- Physical layer
  - Provides the transmission of bits through a communication over the medium or channel by defining electrical, mechanical & procedural specs
- Data link layer
  - Ensures error control & synchronization between two entities
  - Includes Medium Access Control (MAC) & Logical Link Control (LLC)
- Network layer
  - Provides the routing of packets through routers from source to destination
  - Protocols such as IP operate at this layer

Physical (PHY) Layer

WLAN PHY Technology Types

- Narrowband
- Spread Spectrum modulation
  - Frequency-Hopping Spread Spectrum (FHSS)
  - Direct-Sequence Spread Spectrum (DSSS)
- Infrared (IR)

Narrowband Radio Technology

- User information is transmitted & received on a specific radio frequency
- Radio signal frequency is kept as narrow as possible
  - This allows the ability to just pass the information
- Undesirable crosstalk between communication channels is avoided by carefully coordinating different users on different channel frequencies

Narrowband Radio Technology

- Private telephone line is much like a radio frequency
  - Each home in neighborhood has its own private phone line
    - People in one home cannot listen to calls made to other homes
- In a radio system
  - Privacy & noninterference are accomplished by the use of separate radio frequencies
  - Radio receiver filters out all radio signals except the one on its designated frequency
- Drawback
  - End user must obtain an FCC license for each site where it is employed

Spread Spectrum

Technology

FHSS - Frequency Hopping Spread Spectrum

DSSS - Direct Sequence Spread Spectrum

Origins

- Wideband RF technology developed by the military
  - Used for reliable, secure, mission-critical communication
  - Systems are designed to trade off bandwidth efficiency for reliability, integrity & security
    - More bandwidth is consumed than in the narrowband case
    - Tradeoff produces louder & easier to detect signals, provided the receiver knows the parameters of the spread-spectrum signal being broadcast
  - If a receiver is not tuned into the right frequency, a spread-spectrum signal looks like background noise

Technology

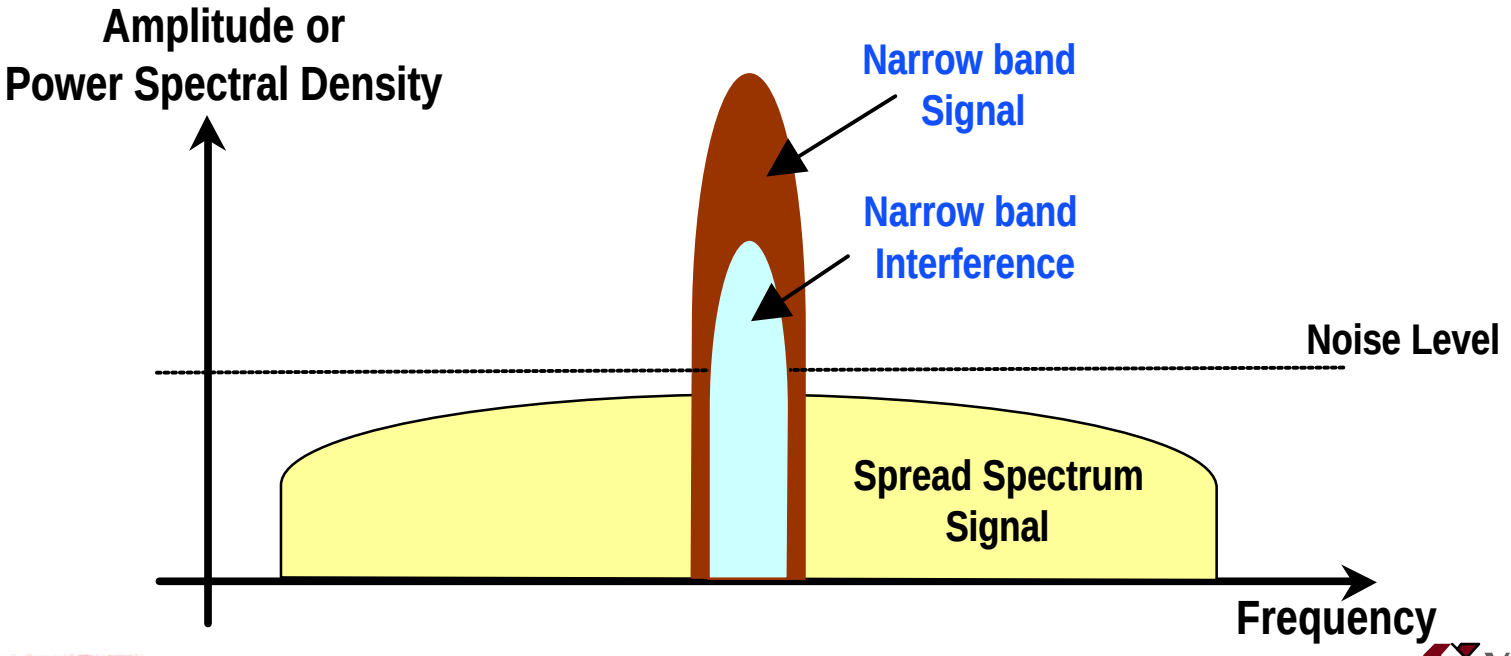
- Physical layer function
- Spread spectrum is a modulation technique or method of transmission where the
  - Radio transceiver prepares the digital signal within the NIC for transmission over the airwaves
  - The transmitted signal occupies a bandwidth considerably greater than the minimum necessary to send the information
  - Some function other than the information being sent is employed to determine the resulting modulated bandwidth

Spread Spectrum Modulation

- Spreads a signal's power over a wider band of frequencies
- Process gain - sacrificing bandwidth to gain signal-to-noise performance
  - Contradicts the desire to conserve frequency bandwidth
  - Spreading process makes the data signal much less susceptible to electrical noise than conventional radio modulation techniques
- Narrow bandwidth transmission & electrical noise
  - Interfere with a small portion of the spread spectrum signal
  - Result in much less interference & fewer errors when the receiver demodulates the signal

Spread Spectrum Modulation

- Frequency spectrum of a data-signal is spread using a code uncorrelated with that signal
  - Codes used for spreading have low cross-correlation values and are unique to every user
  - Sacrifices bandwidth to gain signal-to-noise performance



Spread Spectrum Advantages

- Low power spectral density
  - Spreading the signal over a large frequency-band makes the power spectral density very small
    - However, the Gaussian noise level increases
- Interference limited operation
  - In all situations the whole frequency-spectrum is used
  - Spread spectrum reduces multi-path effects
- Privacy is kept due to unknown random codes
  - Applied codes are unknown to a hostile user
- Random access possibilities
  - Users can start their transmission at any arbitrary time

How Does SS Work?

- Receivers should be assigned different codes
  - It will address them away from other receivers with different codes
- Codes with low cross correlation properties should be chosen to minimize interference between groups of receivers
- Selective addressing and Code Division Multiple Access (CDMA) are implemented via these codings

How Does SS Work?

- Power spectrum spreads out with spreading the intelligence of a signal over several MHz of spectrum
  - It makes the detection of the none-coded signals very difficult
- By increasing the bandwidth Signal/Noise may be decreased without decreased BER performance

C = W log2 (1+ S/N)
C = Channel capacity in bits
W = Bandwidth in Hertz
S = Signal Power
N = Noise Power

Types

- Spread spectrum modulators use one of two methods to spread signal over a wider area
  - Frequency Hopping
  - Direct Sequence

FHSS
Frequency Hopping Spread Spectrum

- It works very much like its name implies
  - Frequency hopping
    - Data signal is modulated with a narrowband carrier signal that hops from frequency to frequency as a function of time over a wide band of frequencies
    - Relies on frequency diversity to combat interference
      - This is accomplished by multiple frequencies, code selection & FSK
  - E.g., A FH radio will hop the carrier frequency over the 2.4GHz frequency band between 2.4GHz & 2.483GHz
    - If the radio encounters interference on one frequency, the radio will retransmit the signal on a subsequent hop on another frequency

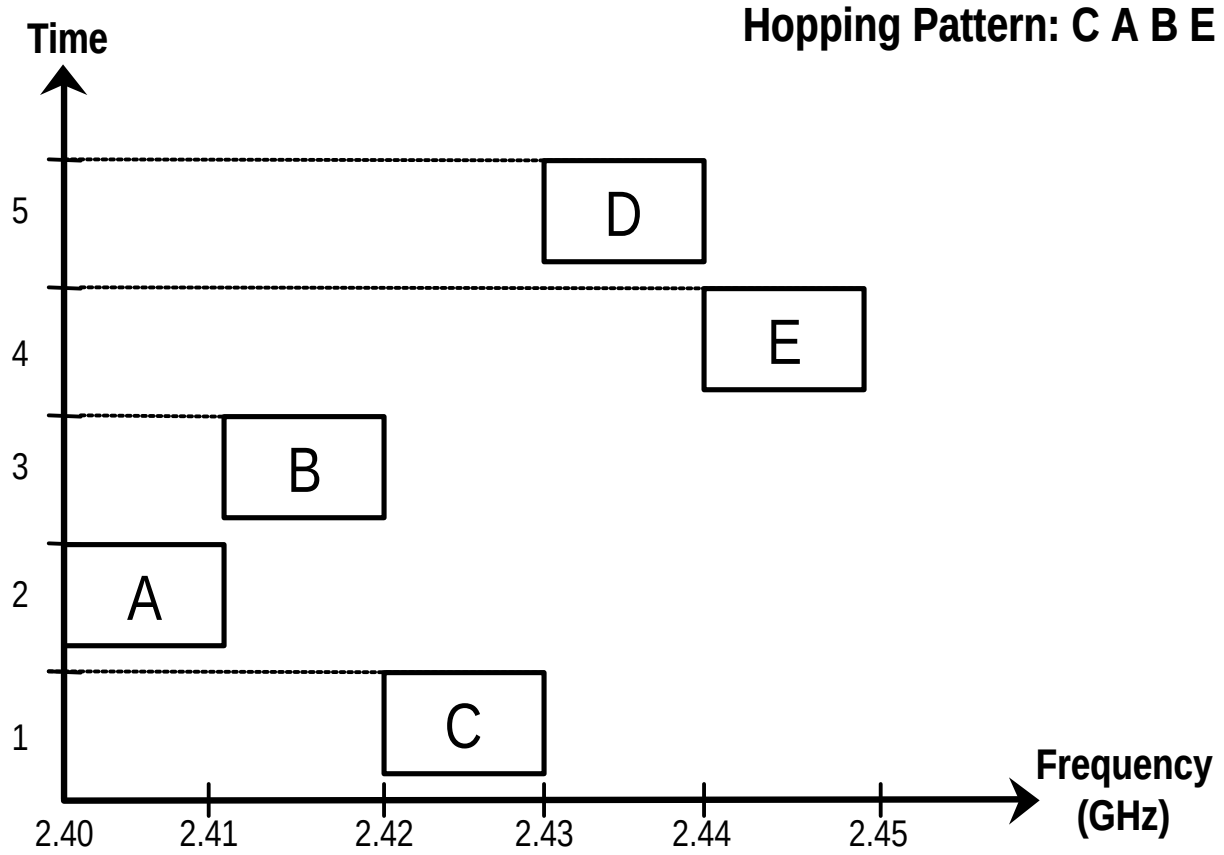
FHSS Technology

- Hopping code determines the frequencies the radio will transmit and in which order
  - Hopping pattern is known to both transmitter & receiver
    - To properly receive the signal the receiver must be set to the same hopping code & listen to the incoming signal at the right time & correct frequency
  - If properly synchronized the net effect is to maintain a single logical channel
- Unintended receiver see FHSS to be short-duration impulse noise

FHSS Technology

- FHSS system must hop its whole information signal over a band of frequencies of the ISM band in use
  - Does not interfere with primary user
- Because of the nature of its modulation technique frequency hopping can achieve up to 2Mbps data rates
  - Faster data rates are susceptible to huge number of errors
- Frequency hopping technique reduces interference
  - An interfering signal from a narrowband system will affect the spread spectrum signal only if both are transmitting at the same frequency at the same time
  - Aggregate interference will be very low, resulting in little or no bit errors

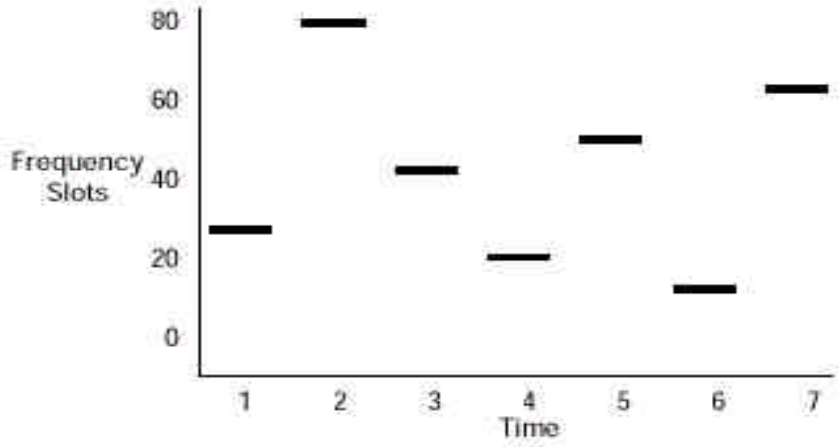
FH Example



With FHSS, the Carrier Frequency Changes Periodically - The incoming digital stream is shifted in frequency by an amount determined by a code that spreads the signal power over a wide bandwidth

FHSS Example for One Channel

- 7 frequency slots exist in the band
  - System send the information signal in frequency slot 24 for the first time slot, then frequency slot 78 for the second time slot, then frequency slot 42 for the third time slot, and so on
- Users wishing to receive signals must tune receiver to particular frequency slot
  - To receiver channel number 1 must tune its receiver to frequency slot 24 for first time slot, frequency slot 78 for the second time slot, then frequency slot 42 for the third time slot, and so on



Different FH Pattern

- Each channel is a different frequency hopping pattern
  - Channels are distinguished between channel 1 & channel 2 by having a different frequency hopping pattern
  - Receiver of channel 2 must hop his receiver according to the channel 2 FH pattern
  - This is not a different frequency as in Frequency Division Multiplexing - it is a different Frequency Hopping Pattern
    - In FDM each channel simply stays on one frequency slot for the duration of the transmission

Different FH Pattern

- It is possible to have operating radios use spread spectrum within the same frequency band & not interfere
  - Such that they use a different hopping pattern
  - While one radio is transmitting at one particular frequency the other radio is using a different frequency
    - A set of hopping codes that never use the same frequencies at the same time are considered *orthogonal*

FHSS Products

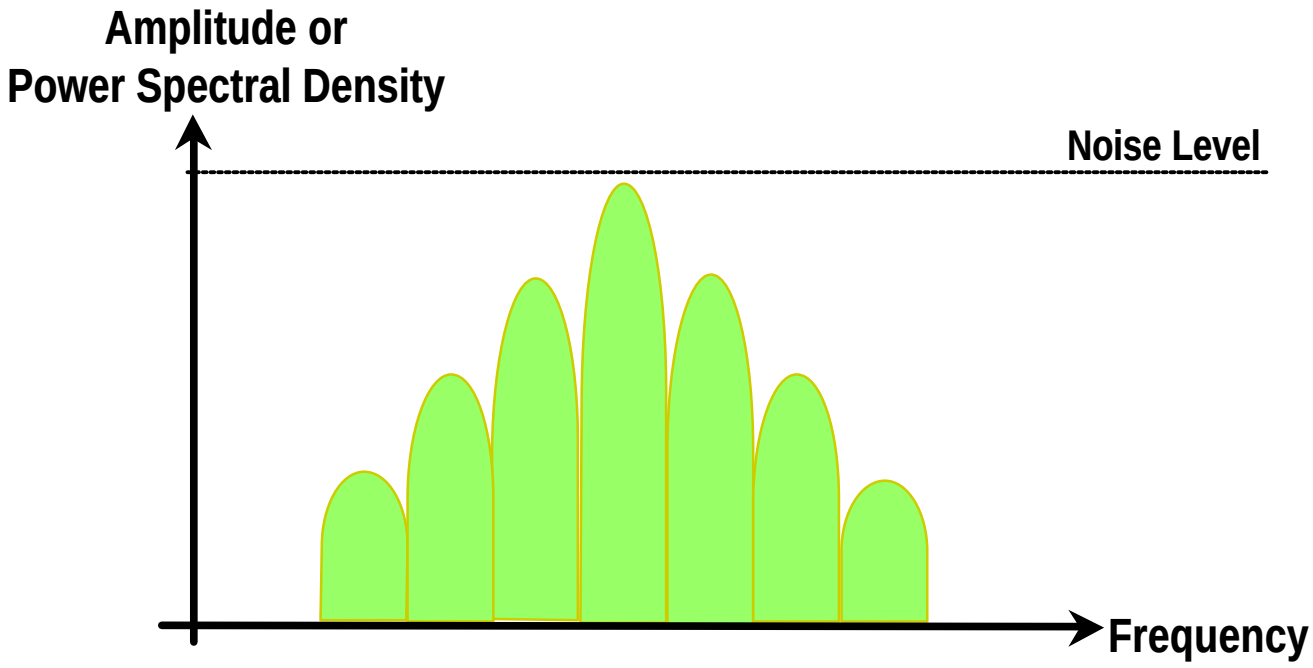
- The FHSS transmitter is a pseudo-noise PN code controlled frequency synthesizer
  - The instantaneous frequency output of the transmitter jumps from one value to another based on the pseudo-random input from the code generator
  - Varying the instantaneous frequency results in an output spectrum that is effectively spread over the range of frequencies generated

DSSS

- Direct Sequence Spread Spectrum
- Most widely recognized form of spread spectrum
- The DSSS process is performed by effectively multiplying an RF carrier and a pseudo-noise (PN) digital signal
  - First, the PN code is modulated onto the information signal using one of several modulation techniques (eg. BPSK, QPSK, etc.)
  - Then, a doubly balanced mixer is used to multiply the RF carrier and PN modulated information signal
  - This process causes the RF signal to be replaced with a very wide bandwidth signal with the spectral equivalent of a noise signal

DSSS

- The signals generated with this technique appear as noise in the frequency domain
  - The wide bandwidth provided by the PN code allows the signal power to drop below the noise threshold without loss of information



DSSS
Direct Sequence Spread Spectrum

- Combines a data signal at the sending station with a higher data rate bit sequence
  - High processing gain increases the signal's resistance to interference
- A chipping code is assigned to represent logic 1 and 0 data bits
  - As the data stream is transmitted, the corresponding code is actually sent

Chipping Code: 0 = 11101100011
1 = 00010011100

Data Stream: 101

Transmitted Sequence:

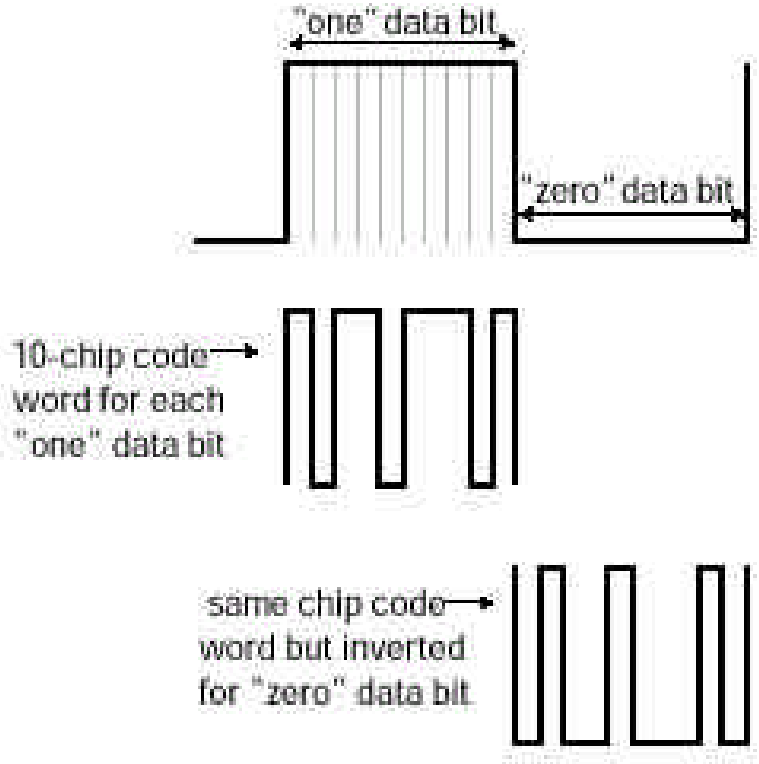
00010011100	11101100011	00010011100
1	0	1

Example: DSSS sends a specific string of bits for each data bit sent - The transmission of a data bit equal to 1 would result in the sequence 00010011100 being sent

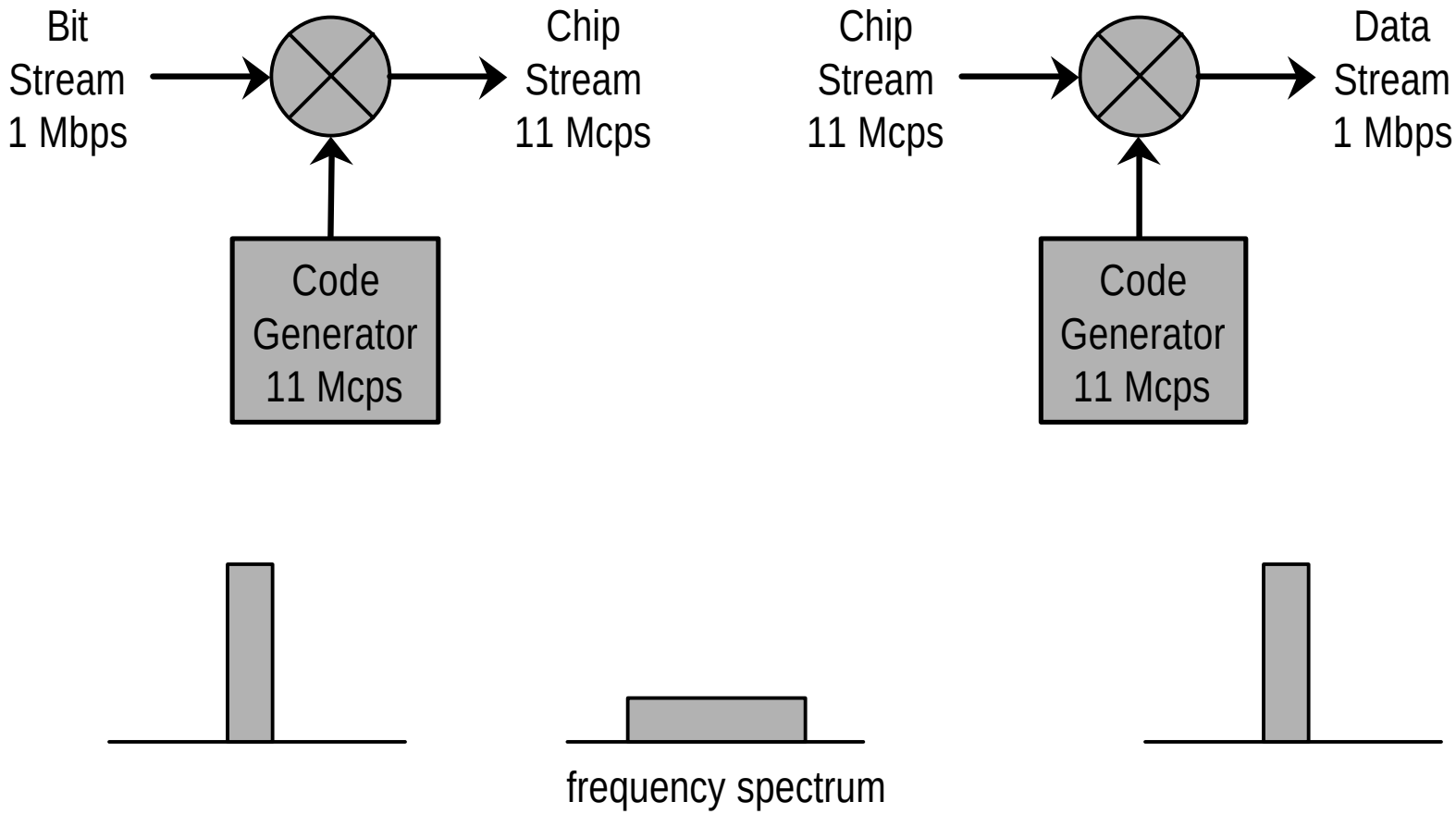
DSSS Technology

- Generates redundant bit pattern for each bit to be transmitted
  - This bit pattern is called chip/chipping code (processing gain)
  - Longer the chip
    - Greater is the probability that the original data will be recovered
    - More is the bandwidth that is required
  - If one or more bits are damaged during transmission
    - Statistical techniques embedded in the radio can recover the original data without the need for retransmission
- Unintended receivers
  - View DSSS as a low-power wideband noise & is ignored or rejected by most narrowband receivers

DSSS Technology



DSSS


Bit
Stream
1 Mbps
Chip
Stream
11 Mcps
Code
Generator
11 Mcps
Chip
Stream
11 Mcps
Data
Stream
1 Mbps
Code
Generator
11 Mcps
frequency spectrum

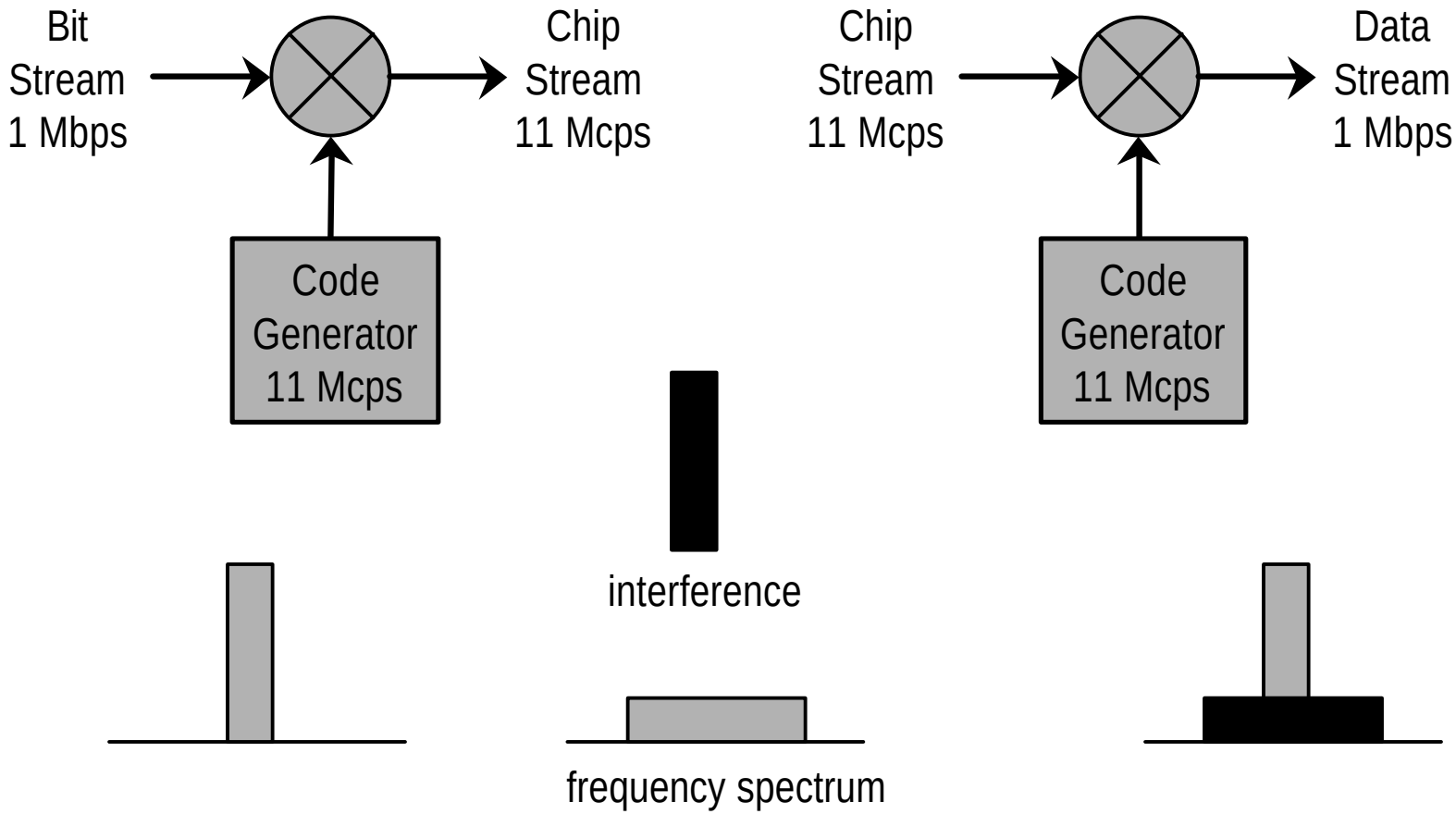
DSSS Operation

- Input data stream
  - Runs at 1Mbps
  - Multiplied by a chip stream running 11 times faster at 11 Mcps
- A chip is exactly like a bit - zero or one,
  - Called chip only to be distinguished from a bit
  - More chips exist than do bits
- When the bit stream is multiplied, its frequency spectrum becomes spread out
  - Occupies about 11 times as much bandwidth, spectral energy is 11 times lower
  - Since it is so low it does not interfere with the the primary user

DSSS Operation

- With more DSSS systems occupying the band, the overall noise level (interference) rises
  - Causes degradation in performance
  - Causes primary user to increase a bit
    - Increased interference to DSSS users are expected to become a problem long before the primary user notices any interference
- At the receiver
  - Input chip stream is multiplied by the same coded chip stream that was used at the transmitter
  - Two codes are synchronized
    - Original bit stream is correlated
    - Any interference on the air when it goes through the correlator becomes spread out

DSSS With Interference



Interference in DSSS

- Amount of interference energy is reduced by the spreading factor
  - Anti-jamming effect makes DSSS technology useful for defense applications
  - DSSS continues to operate at stated throughput
- As more interference is introduced in the channel
  - Noise level increases until even though it is spread out by the correlator, it still becomes too much for the DSSS system to operate
  - DSSS system stops working and throughput declines to zero

DSSS Properties

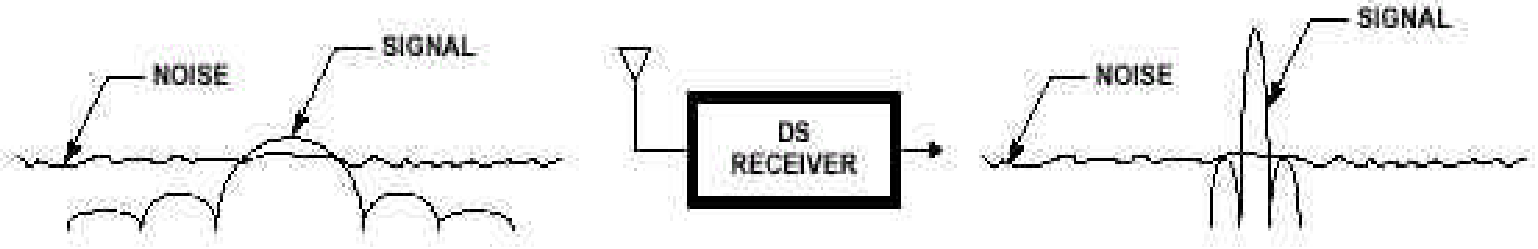


FIGURE 2A. LOW POWER DENSITY

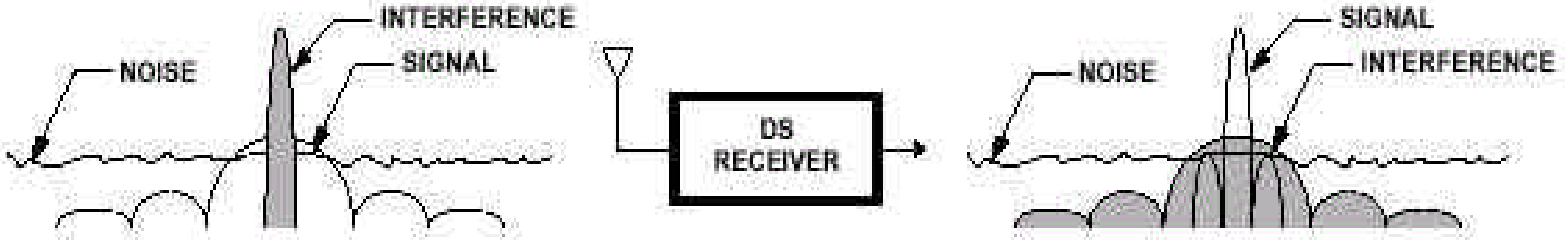
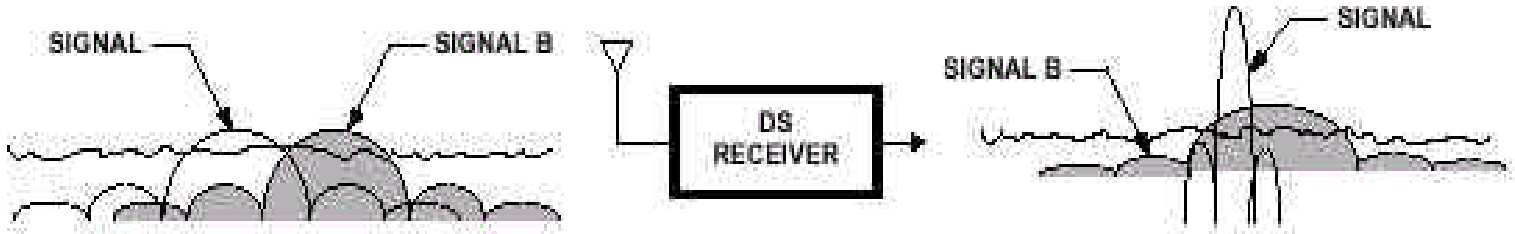


FIGURE 2B. INTERFERENCE REJECTION



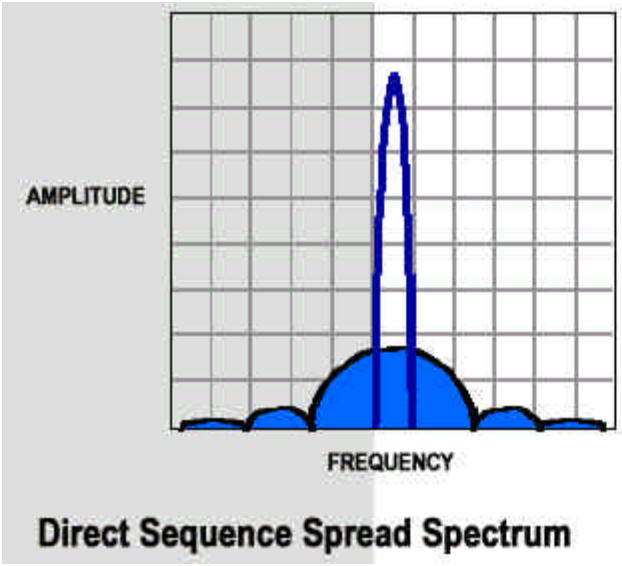
Source: Intersil

Processing Gain Information

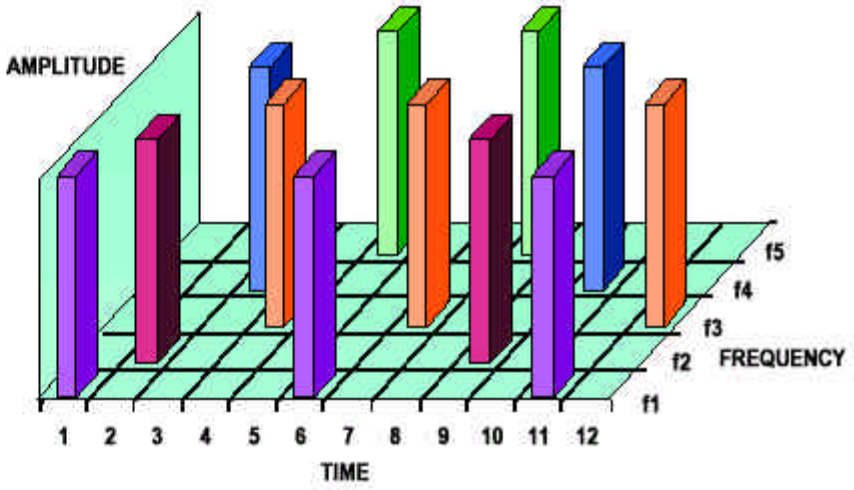
- Minimum linear processing gain allowed by the FCC is 10
- Most commercial products operate under 20
- IEEE 802.11 Working Group has set its minimum processing gain requirements at 11

Spread Spectrum Summary

- Transmission bandwidth is greater than the information data rate
- Code signal spreads the original signal
- Spread and de-spread codes are the same



Direct Sequence Spread Spectrum



Frequency Hopping Spread Spectrum

Source: Compaq

DSSS vs. FHSS Comparison

Direct Sequence (DS)	Frequency Hopping (FH)
Higher Throughput	Interference immunity
Wider Range	Echo resistant
Upgradeable to higher speeds at 2.4GHz	Less expensive than DS systems
	Simpler installation
	More extensive product selection, more vendors

- FHSS degrades gradually, DSSS degrades drastically!
- DSSS can achieve much higher data rates than FHSS's 2Mbps
- FHSS can have up to 10 or 15 channels, while DSSS can have up to 2 or 3 channels

DSSS vs. FHSS Comparison

- Instantaneous data rates of DSSS can be larger than FHSS
  - In FHSS the maximum bandwidth of the signal is specified to 1MHz at the 2.4GHz band
    - Realistic data rates are limited to 1 or 2 Mbps
  - With DSSS, the rule is to spread by at least a factor of 11
    - Theoretically it is possible to use the whole 80 MHz band & provide a data rate in the order of 6 or 7 Mbps
    - Circuitry would be required to run at a very high rate of 66 or 77 Mbps in order to generate the chip stream necessary to support the 6 or 7 Mbps bit rate
    - This high rate would be very expensive & not seen in the industry at this time

Infrared (IR) Technology

- IR systems use very high frequencies, just below visible light in the electromagnetic spectrum to carry data
- IR cannot penetrate opaque objects and uses
  - Directed (line-of-sight) technology
    - Inexpensive directed systems
      - Provide very limited range - 3ft
      - Used for personal area networks & occasionally in wireless LAN
    - High performance directed IR
      - Impractical for mobile users & used only to implement fixed subnetworks
  - Diffuse (or reflective) IR technology
    - Line-of-sight is not required & cells are limited to individual rooms
- Little used in commercial wireless LANs

Non-Interoperable PHYs

- DSSS radio cannot interoperate with a FHSS radio
- FHSS radio cannot interoperate with a DSSS radio
- Neither a FHSS nor DSSS radio can interoperate with IR
- The 3 types of PHY layers are due to legacy issues

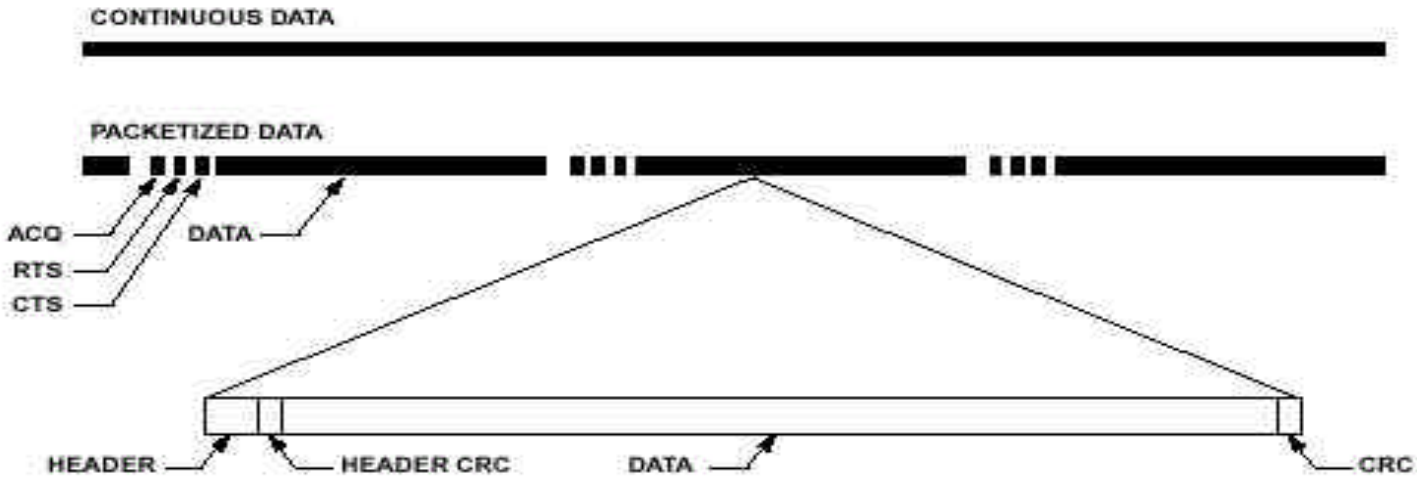
Radio Waves

- Referred to as radio carriers because they simply perform the function of delivering energy to a remote receiver
- Data being transmitted is superimposed on the radio carrier so that it can be extracted at the receiving end
  - Modulation of the carrier by information being transmitted
  - The radio signal occupies more than a single frequency, since the frequency or bit rate of the modulating information adds to the carrier

Radio Waves

- Multiple radio carriers exist in same space at same time
  - No interference between radio waves if they are transmitted on different radio frequencies
- Data extraction
  - Radio receiver tunes in one radio frequency rejecting all other frequencies

Packetized Communications



Source: Intersil

- Packet radio or packet communications
  - Breaking up of a large block of data into small “packets” is a common technique in communications
    - Insures error free communication even with interruptions
    - Packet communications is a term used where the communication medium is not well controlled & can be interrupted
    - There are numerous reasons why a radio communications link may be interrupted, such as the microwave oven

Packetized Data

- If the medium is corrupted intermittently, a large block of data will never make it through without errors
- In the packet technique
  - Block of data is broken into small packets that each have some error detection bits added
  - If an error is detected, a retransmission of the small packet that was corrupted will not burden the network
  - This packet communications technique has short control packets that check to see if the medium is clear, the other end is ready to receive and, to request a retransmission if a packet did not get through correctly
  - All of this requires some overhead expense that reduces the net system throughput

Packetized Data

- Packet length can be optimized
  - This minimizes overhead while insuring the greatest throughput & data integrity
  - When continuous data is packetized, the instantaneous rate must increase since the time allowed for data transmission is reduced
  - This allows time for the packet protocol interchange, packet headers and other overhead

Data Link Layer

Medium Access Control (MAC)

Logical Link Control (LLC)

Data Link Layer

- Provides a reliable, efficient communication protocol between machines physically connected machines communicating over a channel
- Functions
  - Provide services to the network layer
  - Framing
    - Determines the grouping of the physical layer bits into frames
  - Error control (detection and correction)
    - Deals with transmission errors
  - Flow control
    - Regulates the flow of frames so that the slow receivers are not swamped by fast senders

Medium Access Control Sub-layer

- Sub-layer of the data link layer
- Determines priority & allocation to access the channel

MAC Protocol Alternatives

- Random access
  - ALOHA, CSMA (with CD)
- Ordered access
  - Token bus, token ring
- Deterministic access
  - FDMA, TDMA, CDMA
- Combinations
  - FDMA/TDMA, CDMA/TDMA, TDMA/CSMA

Logical Link Control (LLC) Sub-layer

- Sub-layer above the MAC
- Framing/Frame construction takes place here
  - LLC inserts certain fields in the frame such as source address & destination address at the head end of the frame & error handling bits at the end of the frame

It is Not Like a Wired Network?

- Carrier sense
  - In a wired network
    - Means listening to the medium which is the network cable
  - In a wireless network
    - Defining the cable is not straightforward
    - Issue of hidden nodes
      - Is everyone in the Basic Service Area? Or is everyone in the Extended Service Area? Or is it some other set of nodes?

Two MAC Layer Bridging Protocols Within 802.11

- Spanning tree bridges
  - Construct tables of which LAN segment nodes are at any point anytime and age them out if they haven't heard from them
  - Each bridge broadcasts its identity and the identity of other bridges it knows
  - The tree is continuously updated as bridges come and go
  - More popular & more used
- Source routing bridges
  - Rely more on source node which keep a table of where the other nodes are & constructs a network topology
  - Includes the route the packet is to take in the header
  - Heavy load on the nodes resources

What Does the MAC Do?

- Provide access control functions for shared medium PHYs in support of the LLC layer
- MAC layer provides these primary functions
  - Addressing - Accessing the wireless medium
  - Access coordination - Joining the network
  - Frame check sequence generation and checking - Providing authentication and privacy
- MAC layer performs the addressing and recognition of frames in support of the LLC

What Does the MAC Do?

- Accessing the wireless medium
  - CSMA/CA
    - Contention based protocol similar to IEEE 802.3 Ethernet
    - 802.11 specification refers to this mode as distributed coordination function (DCF)
  - Priority based access
    - Contention free access protocol
    - Usable on infrastructure network configurations containing a controller called a point coordinator with the access points
    - 802.11 specification refers to this mode as point coordination function (PCF)

Multiple Access

- Basic access method for IEEE 802.11 is the DCF which uses CSMA/CA
  - Station listens for users
  - If the channel is idle, the station may transmit
  - However if it is busy, each station waits until transmission stops, and then enters into a random back off procedure
    - Prevents multiple stations from seizing the medium immediately after completion of the preceding transmission

How do WLANs Work?

- Electromagnetic waves (radio or IR)
  - Communicate information from one point to another without replying on a physical connection
- Configuration
  - Access points (Transceiver devices)
    - Connect the wired network from a fixed location using standard cabling
    - Receives, buffers & transmits data between wireless LAN & the wired network infrastructure
    - Supports small group of users
    - Functions within a range of 100 to several hundred feet

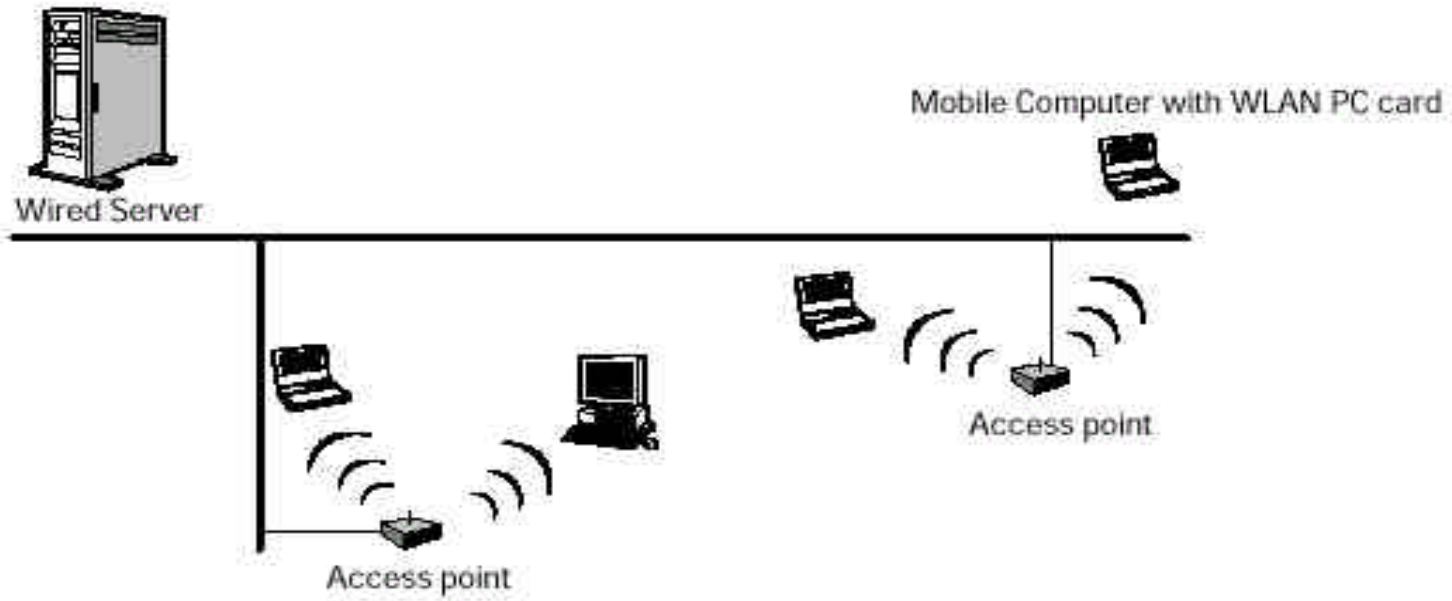
How do WLANs Work?

- Adapters
  - Implemented as PC cards in notebook PCs
  - Provide an interface between the client network operating system (NOS) & the airwaves via an antenna
    - Nature of the wireless connection is transparent to the NOS

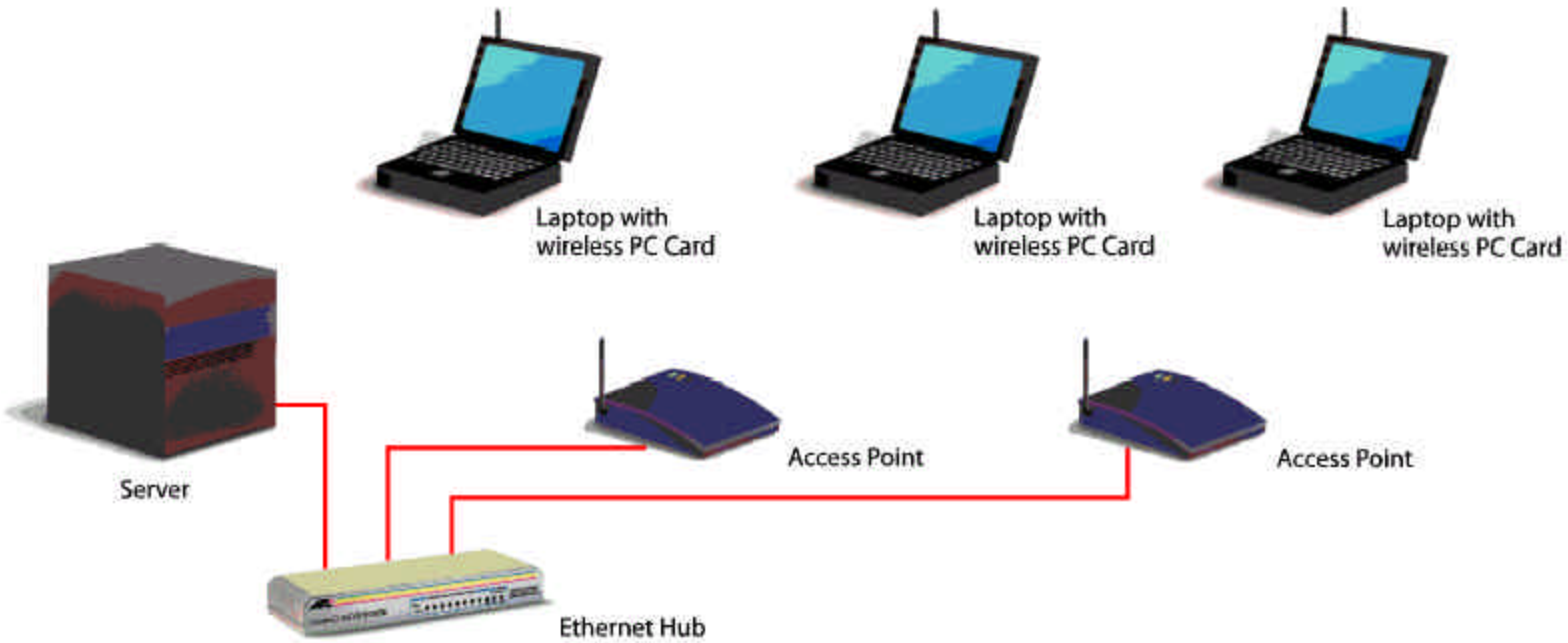
WLAN Configurations

- Wireless peer-to-peer network
- Clients & access points
- Multiple access points & roaming
- Use of an extension point
- Use of directional antennas

Typical WLAN Configuration



Wireless LAN Configuration



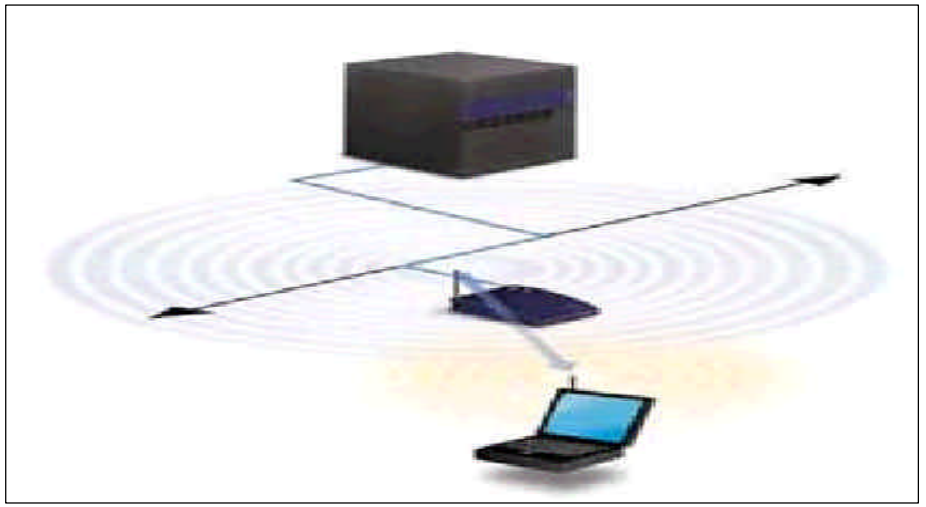
Source: *Proxim*

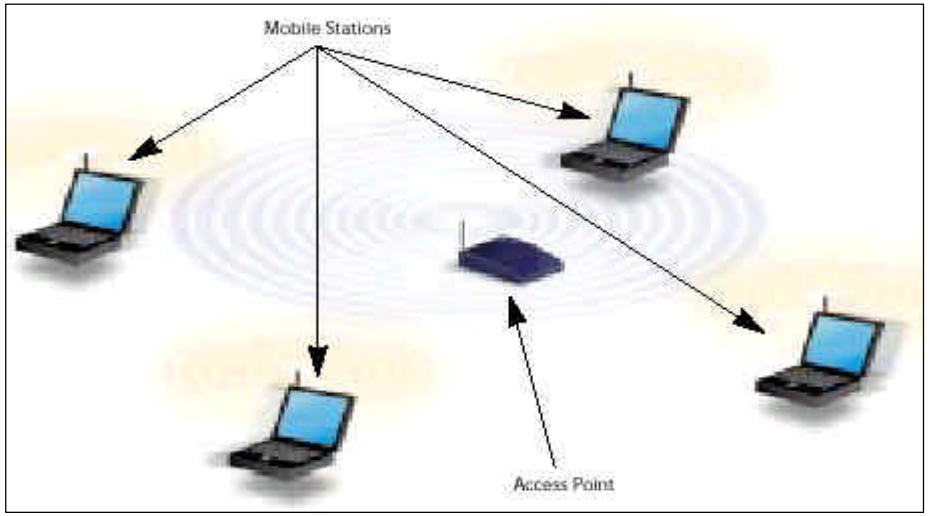
Wireless Peer-to-Peer Network

- Direct communication between devices
- Ad-Hoc Network

Source: *Proxim*

Clients and Access Points





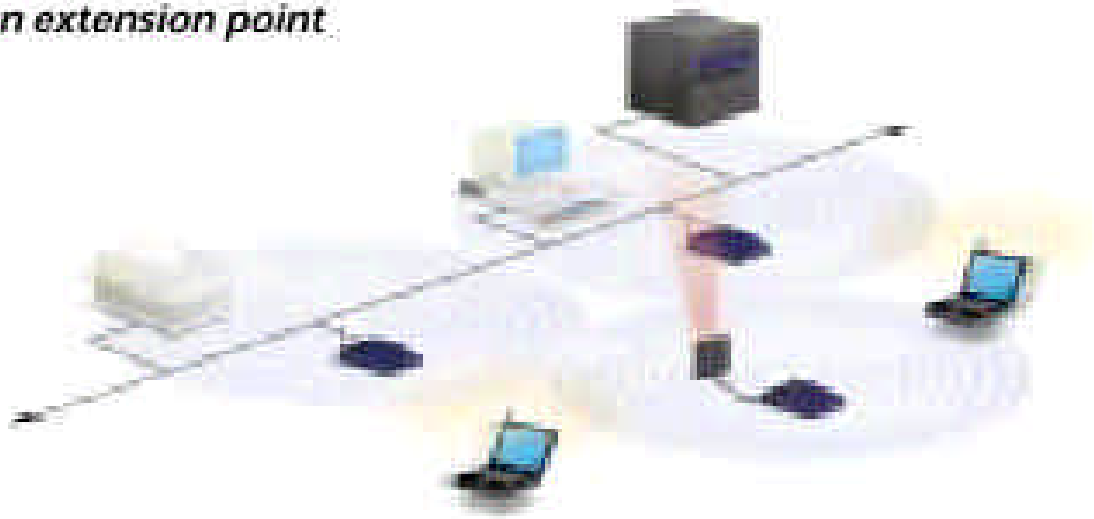
Source: *Proxim*

Multiple Access Points & Roaming

Source: *Proxim*

Extension Point

Use of an extension point



Source: *Proxim*

Emerging WLAN Standards

- HiperLAN & HiperLAN2
- IEEE 802.11 a and b WLAN standards
- Both standards cover the PHY and MAC layers of the OSI network reference model

Interoperability

What is Interoperability?

- It is a key principle upon which modern communication networks are built
- Core concept of network interoperability
  - Simple in concept, but complex in execution
  - Ability of equipment from different manufacturers to work together as each piece was intended to
- Interoperability is made possible by 'Industry Standards'
  - 10BaseT Ethernet card from one firm should be interoperable with the 10BaseT hub built by another firm since they are built to the same spec 802.3 10BaseT standard

Why Do We Need It?

- Why is it a pervasive concern?
  - So many boxes, cables, software options, configurations
  - There are several wireless standards
    - Wireless LAN standards
      - IEEE 802.11
      - Wireless LAN Interoperability Forum's OpenAir
      - ETSI BRAN HiperLAN2
    - HomeRF
    - Bluetooth

Standards-Based Interoperability is of Critical Importance

- Standards encourage the development of a variety of new products
  - Increasing the range of choices available
  - Customers have a large range of products to choose from
    - Extending the standard without creating incompatibilities can be a key product differentiation
- More products means increased competition
  - Lower prices, wider choice of product-specific features beyond standards requirement

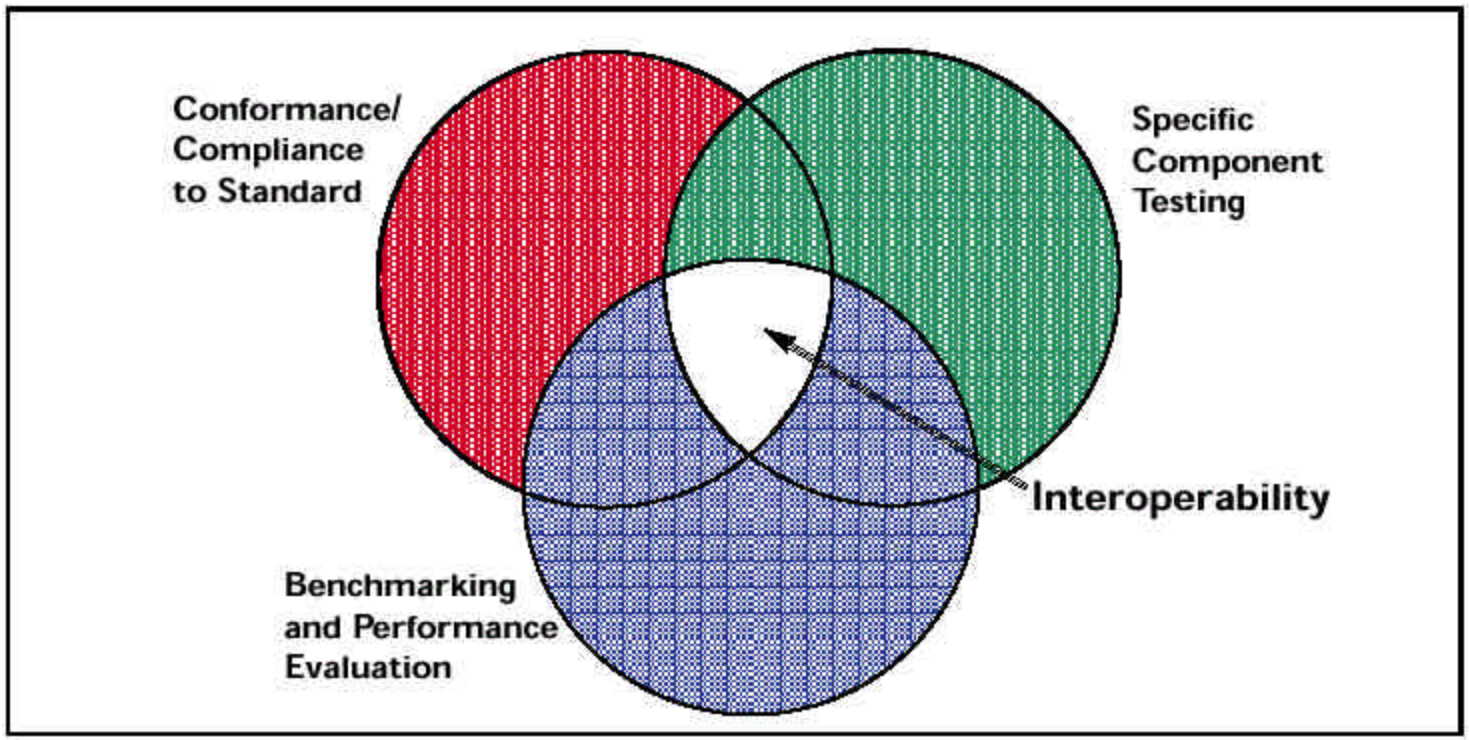
Standards-Based Interoperability is of Critical Importance

- Standards can provide new technologies the foothold needed in an emerging market
  - For example
    - WLANs seem interesting & suitable for an array of applications
    - Standards such as IEEE 802.11 & HiperLAN2 ensure WLANs enjoy rapid growth, see expanding opportunities & fulfil the needs of users

Addressing the Key Concerns

- Concern
  - Does the product really comply with a given standard
- Specialized testing procedures to verify functionality at a number of levels
  - Conformance or compliance to a standard must be verified
    - Test to verify the interface at which standards define interoperability
  - Interoperability between 2 specific components must be tested
    - Accomplished with specialized software suites which exercise the 2 components working together
  - Benchmarking & performance evaluation
    - After interoperability, highest performance is the next requirement

Elements of Interoperability



Source: WLI Forum

Understanding WLAN Interoperability

- Process of WLAN interoperability is similar to wired LANs
- Involves
  - Documentation of test procedures with software suites which verify interoperability
- Factors to consider - PHY Layer
  - Implementations must match meeting local regulations for the particular band being used
    - Involves bandwidth, antenna, power-output limitations
  - Matching PHY layer protocols
    - Such as the use of a particular spread-spectrum modulation technique

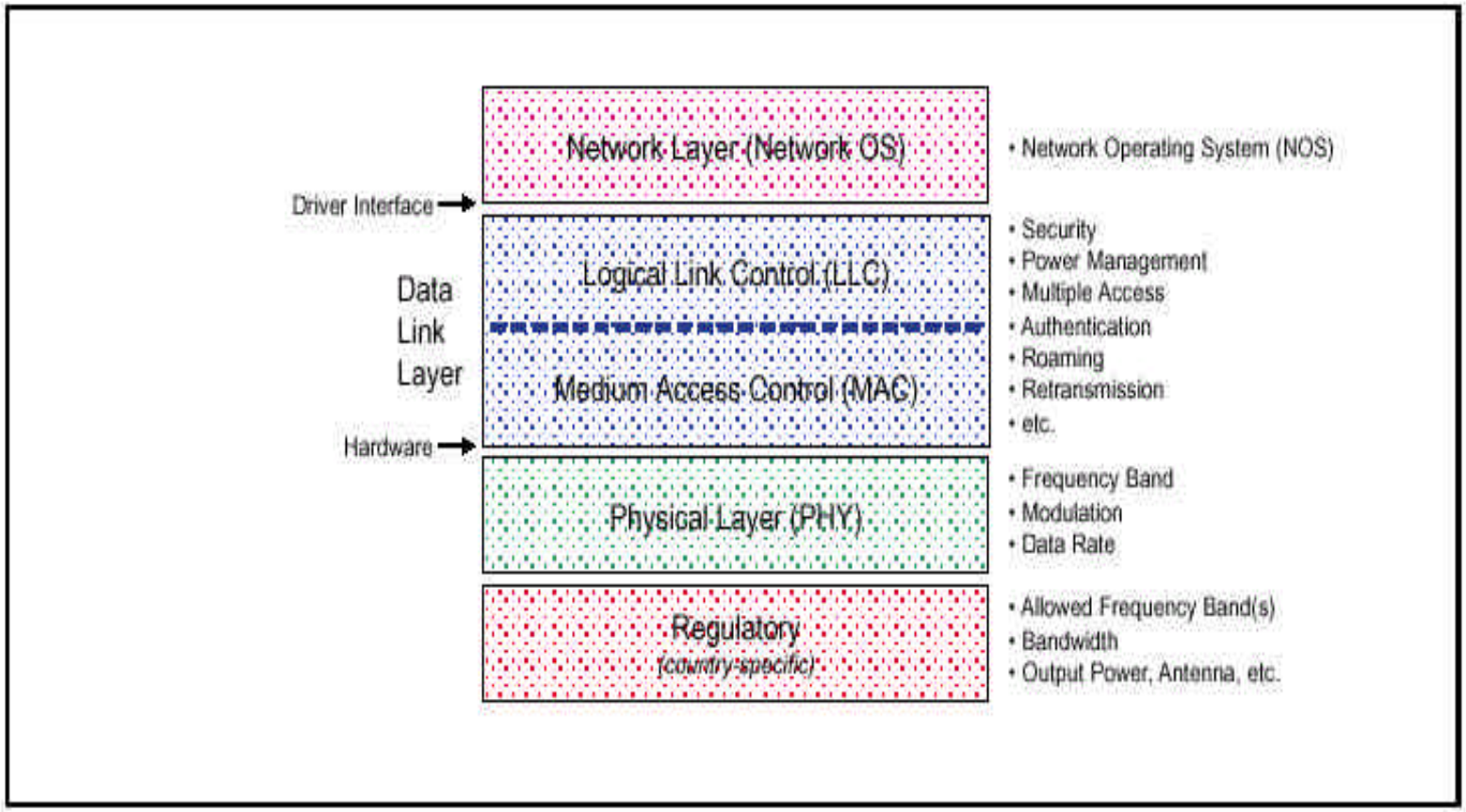
Understanding WLAN Interoperability

- Factors to consider - MAC Layer
  - Support for security, power saving “sleep” modes, automatic retransmission in the event of of an error (ARQ) & others
    - Possible that not all manufacturers will support every feature in a given MAC spec
- Factors to consider - Driver Interfaces
  - Each product must support a set of driver interfaces to specific network operating systems
    - Includes Win9x/NT, Netware and others

Understanding WLAN Interoperability

- Some items can simply not be tested
  - Because they are not part of a standard
    - E.g., Inter-access-point interoperability is not part of the 802.11 standard as each manufacturer defines its own protocol for handoff & load balancing
  - Higher level network functions can be verified with tools that are not specific to PHY layer
- Wireless interoperability needs to be achieved for the whole protocol stack
  - Real applications do not care about the protocol stack

Layers of Reality - Features Supported At Each Protocol Layer



Source: WLI Forum

UNH - IOL

- University of New Hampshire - InterOperability Lab
  - Well known for its work in verifying interoperability between classes of networking devices
- UNH has defined PHY layer tests for DS & FH PHYs
- UNH has a wide range of tests designed to address specific MAC-level features
  - Due to the range of possible combinations MAC-level testing can be both time-consuming & complex

UNH - IOL

- UNH has defined PHY layer tests for DS & FH PHYs
  - Point-to-point interoperability test
    - Verifies that an access point can communicate to a station
  - Packet error test
    - Generates multicast traffic between an AP & multiple STAs
  - Fair access test
    - Generates traffic between an AP & multiple STAs verifying that the STAs are receiving the same amount of traffic
  - Fail over test
    - Makes sure STAs can associate with another AP in event of a failure of the AP currently being used
  - Large network configuration test
    - Examines error rates in WLAN configurations typical of real installations (multiple AP & multiple STAs)

WLIF

- Wireless LAN Interoperability Forum
- Defines a set of procedural tests for verifying interoperability with minimum special software
  - Such tests can be performed under carefully controlled conditions
- Publishes the certified interoperable product information to help customers make more informed purchasing decisions

Additional Tests

- For net throughput and effective range
- Performance-oriented LAN benchmarks
  - Programs which generate synthetic workload for a given class of applications
- Diagnostic tools
  - Such as SNMP or other network management tools
  - Help isolate more subtle interoperability problems
  - Tuning a given installation for maximum throughput, reliability & operation management

Bluetooth (BT)

- Short-range wireless data transmission technology
  - Personal Area Networks (PANs)
  - Provide a simple module that will allow a wide variety of electronic devices to exchange data electronically over short ranges
- Low-cost, low power consumption methods of transmitting data without using wires
- By 2003, BT market could be worth $5 billion (SG Cowen)
- Bluetooth SIG is a huge industry following
  - Ericsson, Nokia, IBM, Intel, Toshiba, Motorola, Lucent, 3Com
  - 2000+ members today

Key Characteristics & Capabilities of BT

- Transmits sound and data
- Used worldwide (standard technology)
- Ad hoc connection
- Open environment, but prevents external reception
- Compact, & able to be installed in a variety of devices
- Extremely low power consumption
- Open industry standard
- Low cost

Issue Between BT & IEEE 802.11

- Coexistence of 802.11 high speed DSSS & BT radios
  - Both radios located in a mixed environment
- Both share common spectrum in the 2.45 GHz ISM band
- Both are largely targeted at the business user & will come in close proximity to each other within enterprise settings
  - The advent of 11Mbps data rates 802.11 DSSS radios
    - Can provide a mobile extension to wired networks in large enterprises & SOHO applications
  - BT will become an important asset for mobile worker & business traveler servicing a number of applications
    - Downloading email to a laptop via cellular phone, synchronizing palmtop devices, accessing local printers

Agenda

- Introduction to wireless home networking
- Wireless LAN technology
- Consortiums
- IEEE 802.11
- HiperLAN & HiperLAN2
- Products & solutions available in the industry today
- Xilinx solutions in wireless LAN products
- Summary

Wireless LAN Consortiums

IEEE 802 Standards Committee

- Formed the 802.11 wireless local area networks standards Working Group developing international WLAN standards since 1990
  - Several drafts standards have been published for review
  - Took on the task of developing a global standard for radio equipment & networks operating in the 2.4GHz unlicensed frequency band at data rates of 1 - 2 Mbps
  - Scope of the standard is to develop a MAC and PHY spec for wireless connectivity for fixed, portable and moving stations within a local area
    - The body does not to specify technologies
  - Allows for manufacturers of WLAN radio equipment to build interoperable network equipment

IEEE 802 Standards Committee

- Purpose/goal of the standard is two-fold
  - Provide wireless connectivity to fixed, portable and moving stations within a local area
  - Standardize access to one or more frequency bands for purpose of local area communications
- Membership
  - Consists of individuals from numerous companies & universities, who research, manufacture, install & use products in WLAN network applications
  - WG core consists of manufacturers of semiconductors, computers, radio equipment, WLAN solution providers University research labs, end-users make up core group
  - Global representation from US, Canada, Europe, Israel, Pacific Rim

Wireless LAN Alliance (WLANA)

- Consisting of 10 members from the wireless LAN market
  - 3Com, Cisco, Intersil, Intermec, Symbol, Xilinx
- Goals
  - Group of component and equipment vendors striving to create greater awareness of wireless technology
  - Provide to managers, end-users, media & businesses:
    - A means of learning the benefits & uses of wireless devices
    - And how it can serve as a competitive advantage in their various vertical markets
  - Evangelize the benefits of wireless networking in horizontal applications with emphasis in wireless activities in the home
    - File sharing, e-mail, scheduling, messaging services

Wireless LAN Interoperability Forum (WLIF)

- Created in May 1996 to develop an open interoperability specification for wireless LAN devices
- Independent from the IEEE 802.11 committee
- Focuses on wireless LAN interoperability
- Key members
  - Casio, Data General, Fujitsu, HP, IBM, Intermec, Mitsubishi, Motorola, Proxim

Wireless Ethernet Compatibility Alliance (WECA)

- Industry alliance supporting a single wireless networking standard – the IEEE 802.11 High-Rate std.
- Group will certify interoperability of products based on the standard 802.11b specifications
  - Similar to WLIF
- The alliance will initiate a marketing campaign
  - Communicates the benefits of interoperability and reduces confusion in the marketplace
- Founding members
  - 3Com, Aironet Wireless Communications (Cisco), Lucent, Nokia, Intersil (Harris Semiconductor), Symbol Technologies

WECA (contd.)

- Products that are standard compliant will be termed “Fast Wireless,” “802.11 High-Rate,” or “Ethernet Wireless”
- WECA hopes to reduce the confusion in the marketplace regarding wireless standards
  - The group will focus on evangelizing the benefits of wireless networking for horizontal applications
    - Distant itself from arguments between equipment vendors
  - WECA plans to market 802.11 High-Rate as a consumer technology for the home networking market as well
    - Group has approached the HomeRF Group about adopting 802.11 High-Rate as their second-generation standard

HiperLAN Committee

- HiperLAN - High Performance European Radio LAN
  - ETSI HiperLAN
  - Bandwidth: 23.529 Mbps
  - Transmission band: 5.15 - 5.25 GHz spectrum
  - Multi-hop routing, time-bounded services and power saving features are expected
  - Members
    - Apple, HP, Harris, IBM, Nokia, Proxim, Intermec, STMicroelectronics

HiperLAN2 Global Forum (H2GF)

- HiperLAN/2
  - Broadband wireless LAN
  - Bandwidth - 54 Mbps, 5GHz spectrum, OFDM PHY
- Members of H2GF
  - Alcatel, Cambridge Silicon Radio, Canon, Dell, Ericsson, Lucent, Intersil, Panasonic, Mitsubishi, Motorola, National Semiconductor, Nokia, NTT, Philips, Samsung, Siemens, Sony, Silicon Wave, Texas Instruments, Toshiba
  - Xilinx

Agenda

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- Consortiums
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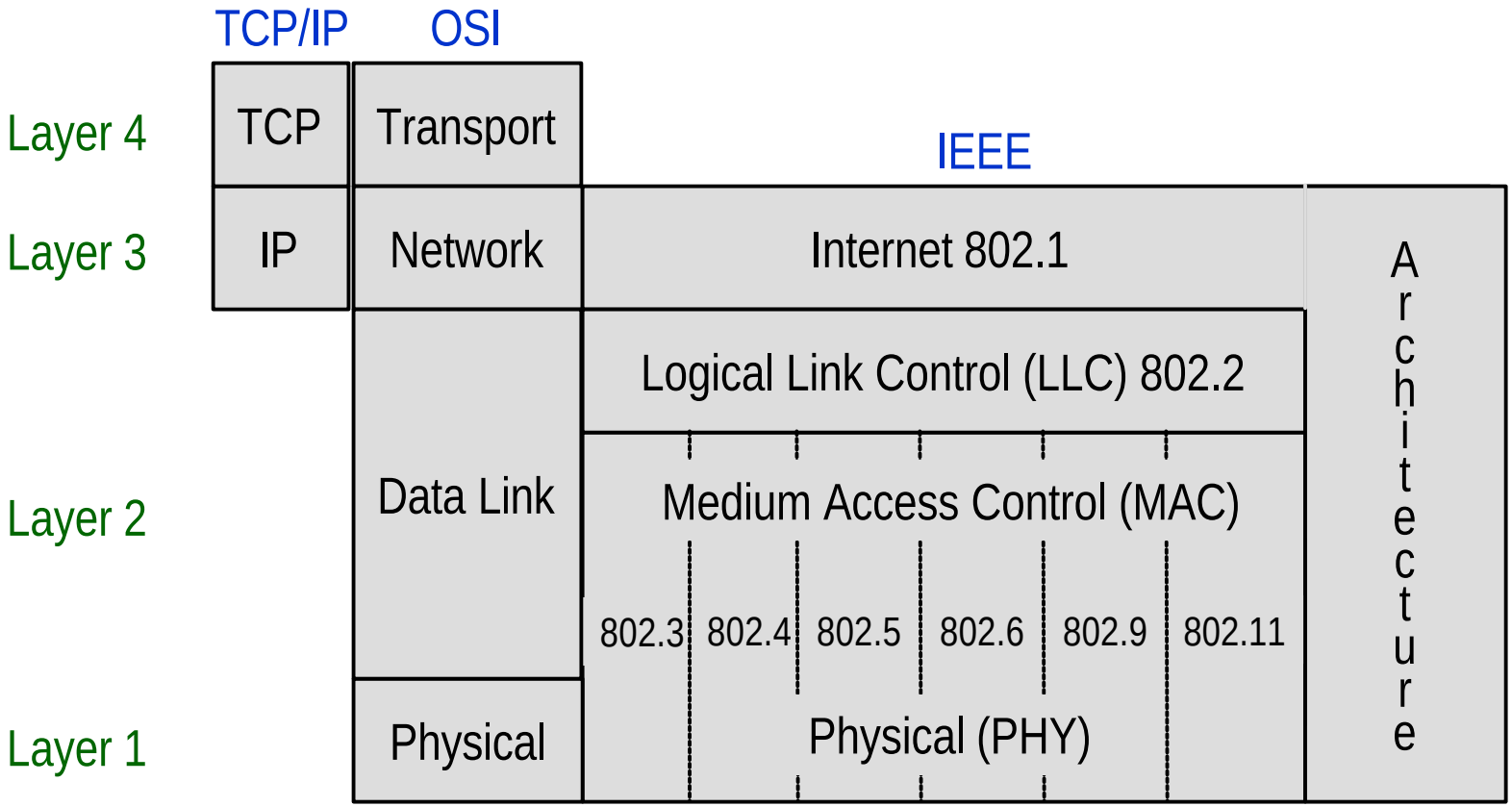
- HiperLAN & HiperLAN2
- Products & solutions available in the industry today
- Xilinx solutions in wireless LAN products
- Summary

IEEE 802.11

Protocol Layers & 802 Protocols



IEEE 802.3 - Ethernet "The Wired LAN"

- Ethernet is CSMA/CD
- CSMA (Carrier Sense Multiple Access)
  - Great for wireless
  - Distributed control with listen before talk
- CD (Collision Detect)
  - Not good for wireless & will not work well in an RF system
  - Transmitting signal hears its own signal perfectly
- Radio has much higher packet error rate

What's Different About Wireless?

- Stations are not always connected
  - Mobility & power management
- Stations destination address does not equal destination location
  - In wired LANs an address is equivalent to a physical location
    - This is implicitly assumed in the design of wired LANs
    - In 802.11, the addressable unit is a station (STA) which is a message destination, but usually not a fixed location
- Packet error rate of RF is much higher than cable
  - Interference is possible from other sources
- Not all stations "hear" the same thing
  - Hidden node problem

What is IEEE 802.11?

- IEEE standard addressing the 2.4 & 5 GHz WLAN market
- Spec is steered by the IEEE committee
  - Specifies “over the air” interface between a wireless client & a base station (or access point) or wireless clients
  - Conceived in 1990, final draft approved in June 1997
  - Like the IEEE 802.3 Ethernet & 802.5 Token Ring Standards
    - Addresses both PHY & MAC Layers

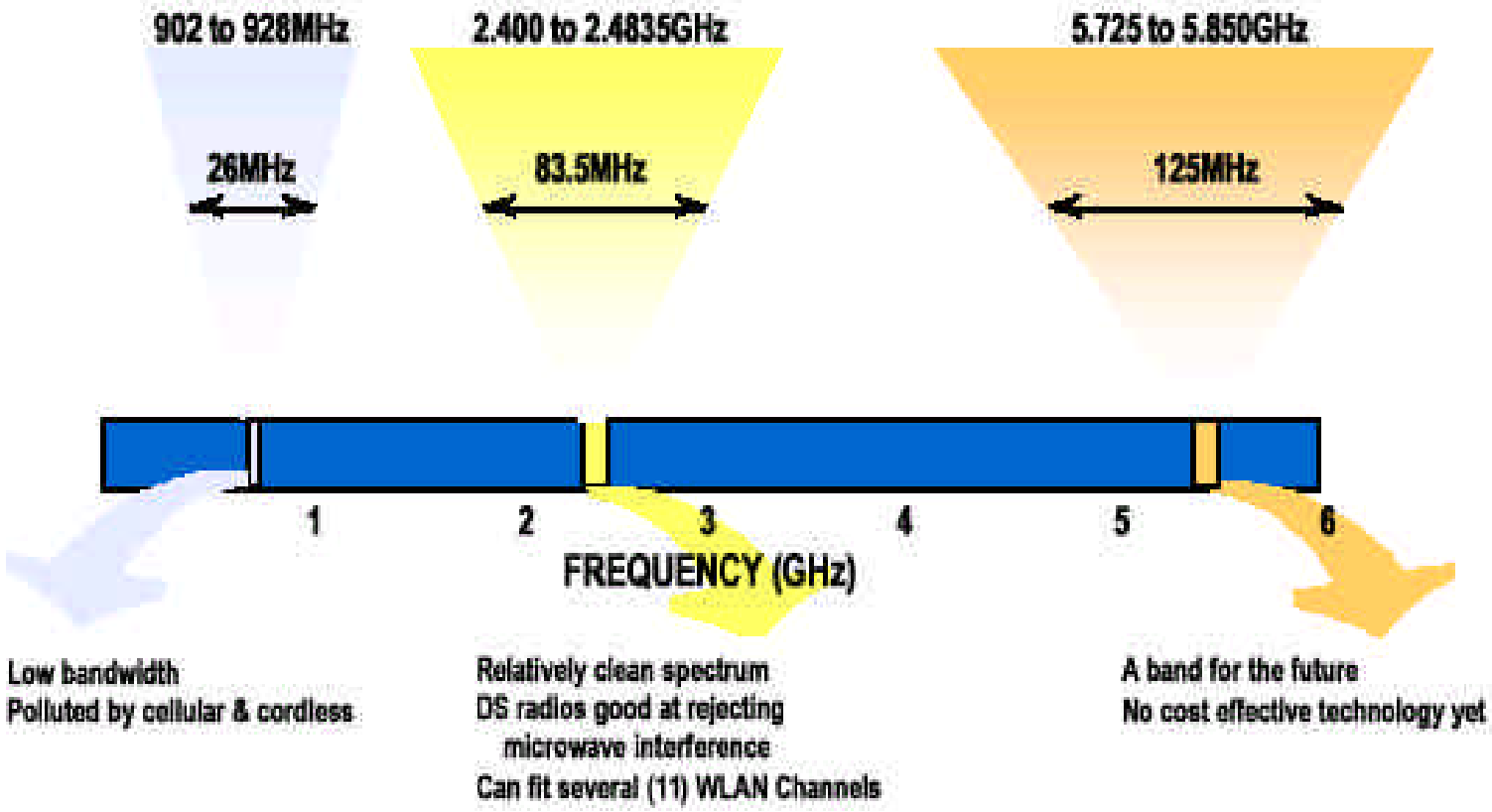
IEEE 802.11 WLAN Standards Requirements

- Providing reliable, efficient wireless data networking
- Defining MAC & PHY layer specifications
- Providing a single MAC layer to work with multiple PHYs
- Allowing for overlapping of multiple networks
- Being robust against interference
- Providing mechanism to handle hidden nodes
- Supporting peer-to-peer & infrastructure configurations
- Supporting time bounded services

IEEE 802.11 Draft Standard Description

- Mandatory support for a 1 Mbps WLAN is specified
  - Optional support for 2 Mbps data transmission rate
- Mandatory support for asynchronous data transfer is specified
  - Asynchronous data transfer refers to traffic that is insensitive to time delay such as available bit rate traffic like e-mail and file transfer
- Optional support for distributed time-bounded services (DTBS)
  - Time-bounded traffic is bounded by specific time delays to achieve an acceptable QoS for packetized voice and video
- Support for 2 fundamentally different MAC schemes to transport asynchronous & time-bounded services
  - DCF (distributed coordination function) & PCF (point coordination function)

ISM Bands



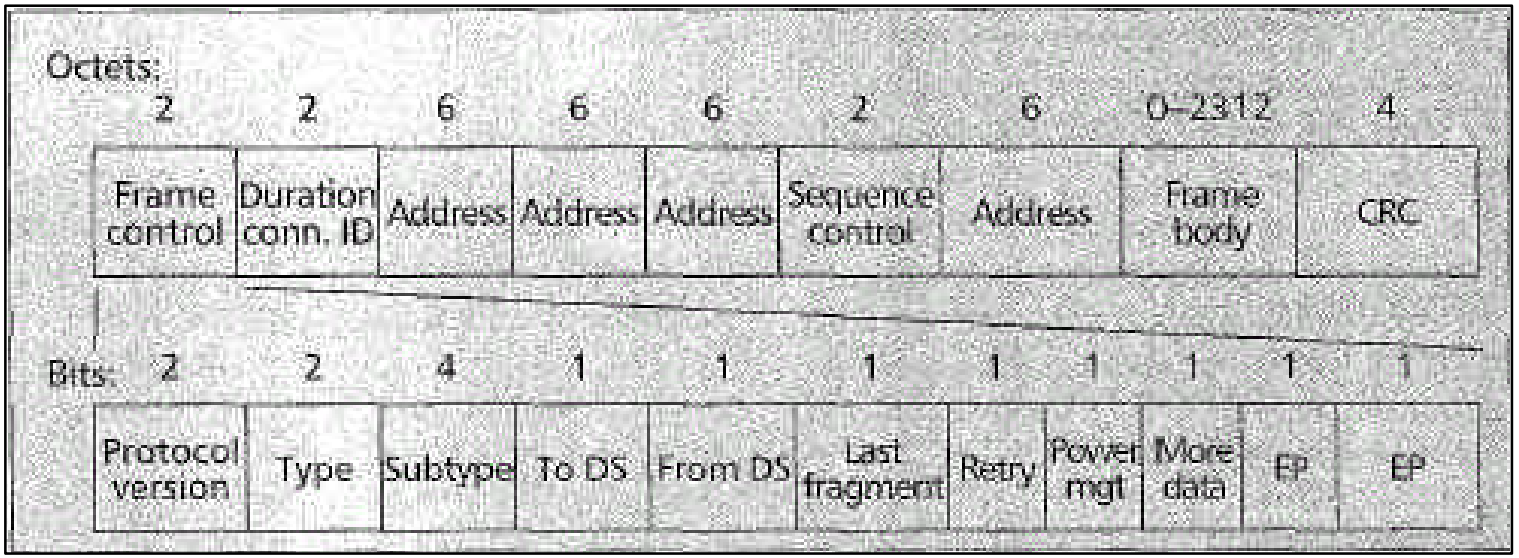
Courtesy: Compaq

2.4GHz ISM Band Channels 802.11 DSSS

CHNL_ID	Frequency	Regulatory Domains					
		10h FCC	20h IC	30h ETSI	31h Spain	32h France	40h MKK
1	2412 MHz	X	X	X	-	-	-
2	2417 MHz	X	X	X	-	-	-
3	2422 MHz	X	X	X	-	-	-
4	2427 MHz	X	X	X	-	-	-
5	2432 MHz	X	X	X	-	-	-
6	2437 MHz	X	X	X	-	-	-
7	2442 MHz	X	X	X	-	-	-
8	2447 MHz	X	X	X	-	-	-
9	2452 MHz	X	X	X	-	-	-
10	2457 MHz	X	X	X	X	X	-
11	2462 MHz	X	X	X	X	X	-
12	2467 MHz	-	-	X	-	X	-
13	2472 MHz	-	-	X	-	X	-
14	2484 MHz	-	-	-	-	-	X

Courtesy: Compaq

Standard IEEE 802.11 Frame Format



Courtesy: IEEE

IEEE 802.11 PHY Layer

- At the PHY layer, IEEE 802.11 defines three physical characteristics for wireless LANs
  - Diffused infrared operating at baseband
  - DSSS operating at 2.4 GHz band - Used in IEEE 802.11b
  - FHSS operating at 2.4 GHz band
- All three PHYs specify support 1Mbps & 2Mbps data rates
  - All 11 Mbps radios are DSSS
  - Choice between FSSS & DSSS depends on the users applications & environment that the system will be operating
- PHY Layer with OFDM operating at 5 GHz band - Used in IEEE 802.11a

802.11 PHY Layer

- 2.4 GHz band
  - Occupies 83 MHz of bandwidth from 2.400 GHz to 2.483 GHz
  - Part of ISM band
  - Global band
  - Primarily set aside for industrial, scientific & medical use
  - Can be used for operating wireless LAN devices without the need for end-user licenses
- Interoperability for wireless devices
  - Requires conforming to the same PHY standard

IEEE 802.11 WLAN Standard Physical Layer Specs

Technology	Frequency Band	Radiated Peak Power Limitation	Modulation Signalling Method	Data Rates
Direct Sequence Spread Spectrum	2.4-2.483GHz	1W for the US, 10mW per 1Mhz in Europe & 10mW for Japan	Differential BPSK (DBPSK) & DQPSK	1Mbps or 2Mbps
Frequency Hopping Spread Spectrum	2.4-2.483GHz	1W for the US, 10mW per 1Mhz in Europe & 10mW for Japan	2-4 level Gaussian FSK	1Mbps
Infrared	850-950nM	2W	4- or 16-level pulse positioning	1Mbps or 2Mbps

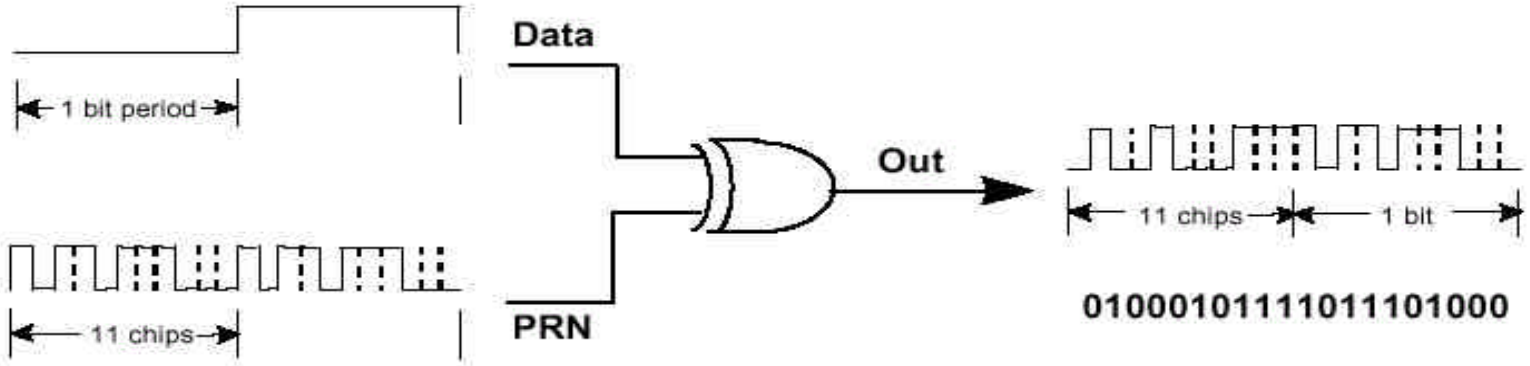
DSSS PHY Layer

- Uses an 11-bit Barker Sequence to spread data before it is transmitted
  - Each bit transmitted is modulated by the 11-bit sequence
  - This process spreads the RF energy across a wider bandwidth than would be required to transmit the raw data
- Processing gain of a system
  - Defined as 10x the log of the ratio of spreading rate (also known as the chip rate) to the data
- Receiver
  - Despreads the RF input to recover the original data

DSSS PHY Layer

- Advantage of the DSSS technique
  - Reduces the effect of narrowband sources of interference
  - Provides 10.4dB of processing gain which meets the minimum requirements for rules set forth by the FCC
- Spreading architecture used in direct sequence is not to be confused with CDMA
  - All 802.11 compliant products utilize the same PN (pseudo-random numerical) code
  - Therefore do not have a set of codes available as is required for CDMA operation

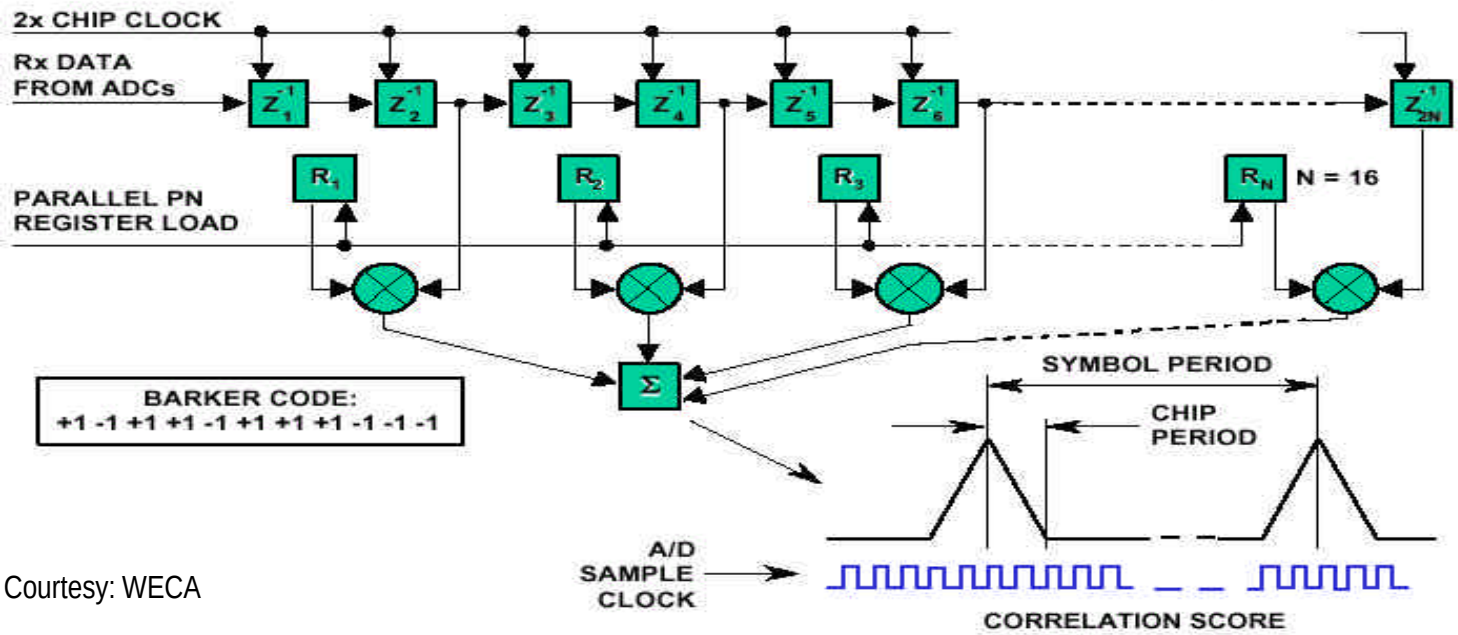
Digital Modulation of Data With PN Sequence



Courtesy: Wireless Ethernet Compatibility Association (WECA)

- DSSS systems use technology similar to GPS satellites and some types of cell phones
- Each information bit is combined via an XOR function with a longer Pseudo-random Numerical (PN) sequence as shown in figure
  - The result is a high speed digital stream which is then modulated onto a carrier frequency using Differential Phase Shift Keying (DPSK)

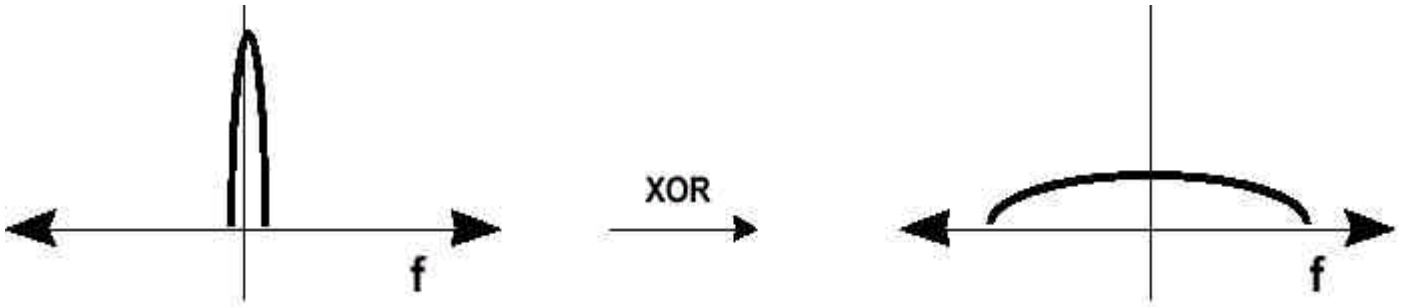
Reception of DSSS Signal



Courtesy: WECA

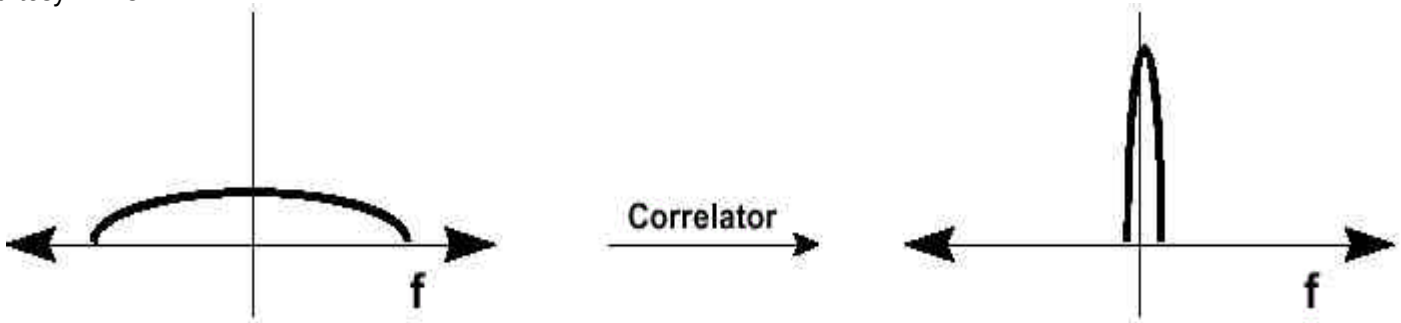
- A matched filter correlator is used for receiving the DSSS Signal
  - Correlator removes the PN sequence & recovers the original data stream
- Complimentary Code Keying (CCK)
  - High rate modulation method
  - To achieve higher data rates of 5.5-11 Mbps DSSS receivers use different PN codes & a bank of correlators to recover the transmitted data stream

Effect of PN Sequence on Transmit & Receive Signal



Effect of PN Sequence on Transmit Spectrum

Courtesy: WECA

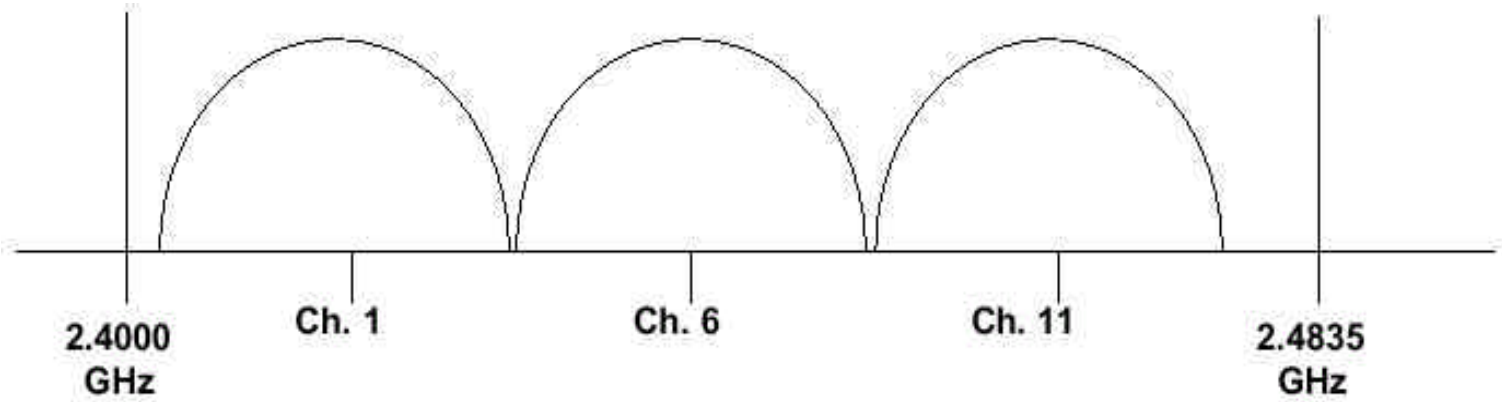


Received Signal is Correlated with PN to Recover Data & Reject Interference

Effect of PN Sequence on Transmit & Receive Signal

- The PN sequence spreads the transmitted bandwidth of the resulting signal
  - Thus the term “spread spectrum”
  - Reduces peak power
    - The total power however remains unchanged
- Upon reception
  - Signal is correlated with the same PN sequence to reject narrow band interference and recover the original binary data

Three Non-Overlapping DSSS Channels in the ISM Band



Courtesy: WECA

- Regardless of whether the data rate is 1, 2, 5.5, or 11 Mbps, the channel bandwidth is about 20 MHz for DSSS systems
- Hence the ISM band will accommodate up to three non-overlapping channels

FHSS PHY Layer

- Has 22 hop patterns to choose from
- Frequency hop physical layer is required to hop across the 2.4 GHz ISM band covering 79 channels
- Each channel occupies 1MHz of bandwidth
  - Must hop at the minimum rate specified by the regulatory bodies of the intended country
    - Minimum hop rate of 2.5 hops per second is specified for the US

PHY Layer Header

- Each physical layer uses their unique header
  - To synchronize the receiver & determine signal modulation format & data packet length
- PHY layer headers are always transmitted at 1Mbps
- Predefined fields in headers provide the option to increase the data rate to 2Mbps for the actual data packet

The MAC Sub-layer

- MAC specification for 802.11 has similarities to 802.3 Ethernet wired line standard
  - CSMA/CA protocol used for 802.11
    - Uses carrier-sense, multiple access, collision avoidance
    - Avoids collisions instead of detecting a collision like the algorithm in 802.3
    - Collision avoidance is used because it is difficult to detect collisions in an RF transmission network

MAC & PHY Layer Operation

- MAC layer operates together with the PHY layer by sampling the energy over the medium transmitting data
- PHY layer uses a clear channel assessment (CCA) algorithm to determine if the channel is clear
  - This is accomplished by measuring the RF energy at the antenna and determining the strength of the received signal
    - This measured signal is commonly known as RSSI
  - If the received signal strength is below a specified threshold the channel is declared clear and the MAC layer is given the clear channel status for data transmission
  - If the RF energy is above the threshold, data transmissions are deferred in accordance with the protocol rules
  - The standard provides another option for CCA that can be alone or with the RSSI measurement

MAC & PHY Layer Operation

- Carrier sense can also be used to determine if the channel is available
  - This technique is more selective sense since it verifies that the signal is the same carrier type as 802.11 transmitters
- The best method to use depends upon the levels of interference in the operating environment
- CSMA/CA protocol allows options to minimize collisions
  - Using request to send (RTS), clear-to-send (CTS), data & acknowledge (ACK) transmission frames in a sequential fashion

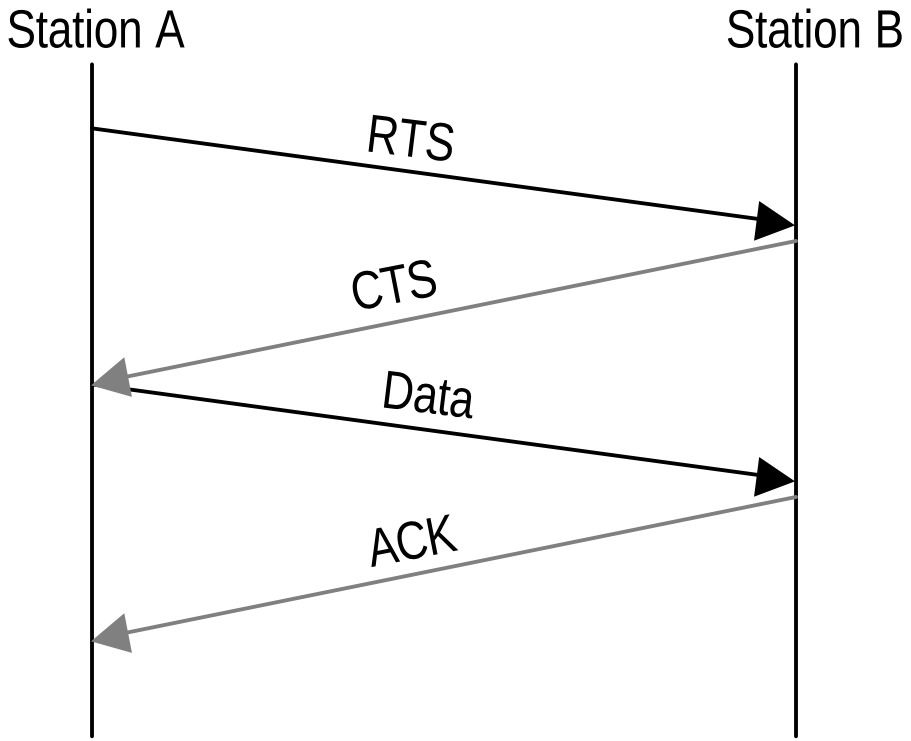
CSMA/CA Protocol Minimizes Collisions

- Communication is established when one of the wireless nodes sends a short message RTS frame
- The RTS frame includes the destination and the length of message
- The message duration is known as the network allocation vector (NAV)
- The NAV alerts all others in the medium, to back off for the duration of the transmission

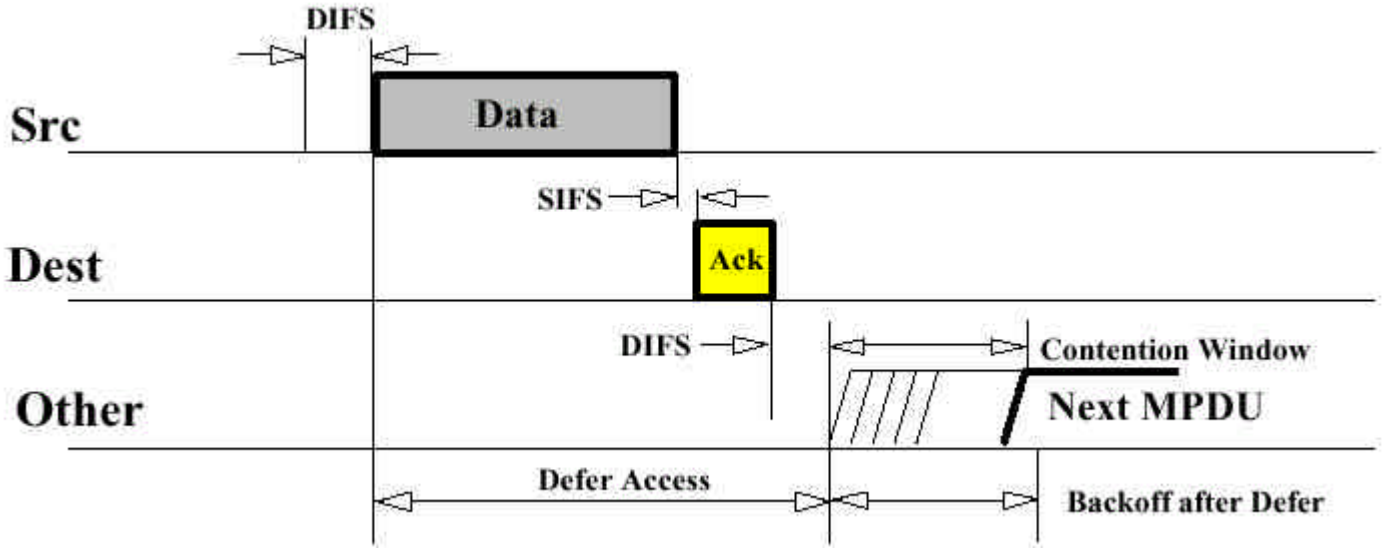
CSMA/CA Protocol Minimizes Collisions

- The receiving station issues a CTS frame which echoes the senders address and the NAV
- If the CTS frame is not received, it is assumed that a collision occurred and the RTS process starts over
- After the data frame is received, an ACK frame is sent back verifying a successful data transmission

RTS/CTS/ACK Protocol



CSMA/CA Back-off Algorithm



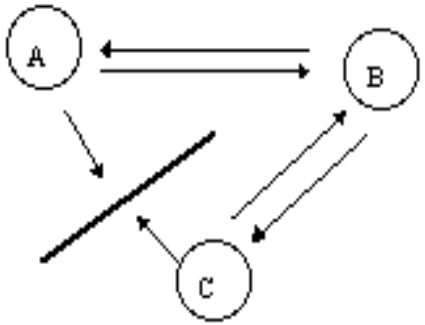
- Packet reception in DCF requires acknowledgment
- The period between completion of packet transmission and start of the ACK frame is one Short Inter Frame Space (SIFS)
- ACK frames have a higher priority than other traffic
  - Fast acknowledgement is one of the salient features of the 802.11 standard, because it requires ACKs to be handled at the MAC sublayer

Hidden Node Problem

- A common limitation with wireless LAN systems is the "hidden node" problem
  - This can disrupt 40% or more of the communications in a highly loaded LAN environment
  - It occurs when there is a station in a service set that cannot detect the transmission of another station to detect that the media is busy

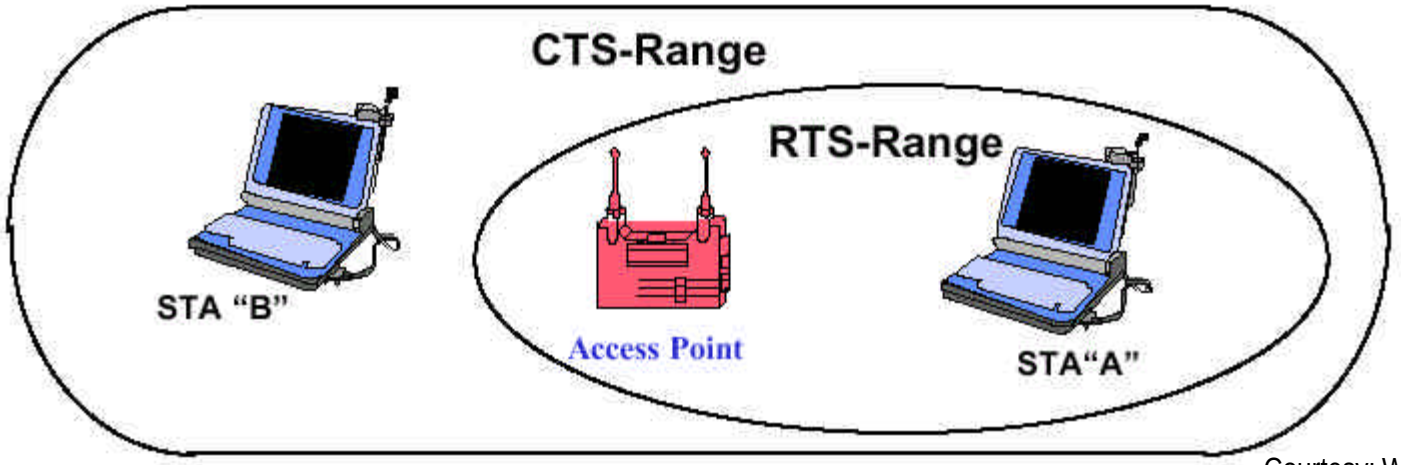
Hidden Node Problem

- The figure shows how stations A and B can communicate
  - However an obstruction prevents station C from receiving station A and it cannot determine when the channel is busy
  - Therefore both stations A and C could try to transmit at the same time to station B
  - The use of RTS, CTS, Data and ACK sequences helps the prevent the disruptions caused by this problem



Courtesy: Wireless LAN Association

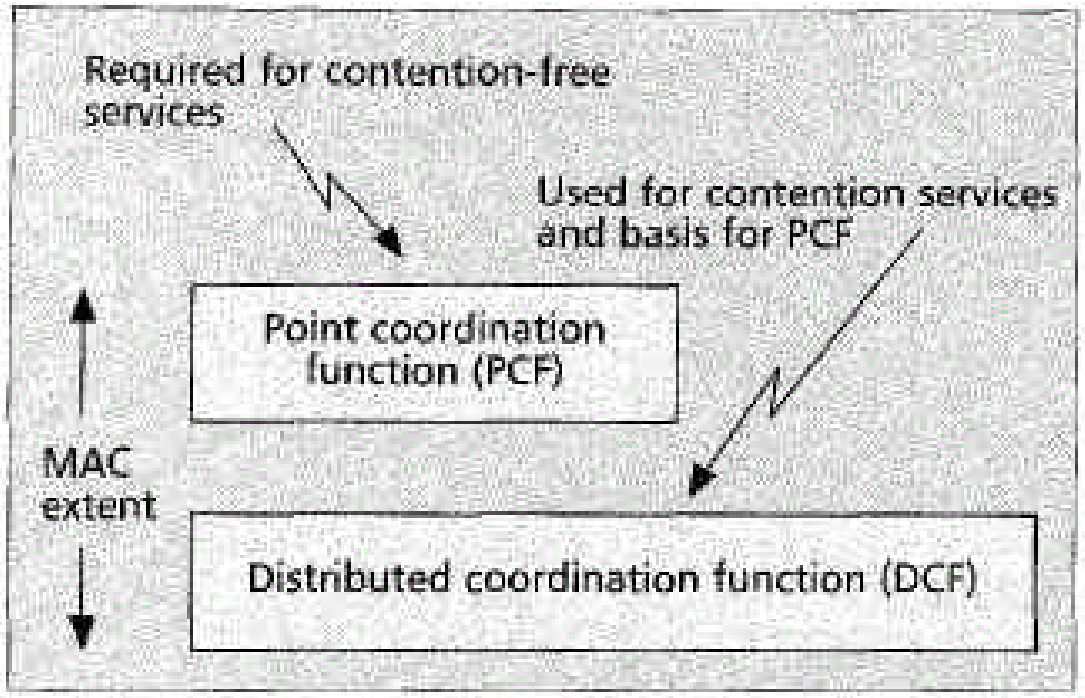
Hidden Node Example



Courtesy: WECA

- From the figure
  - The AP is within range of the STA-A, but STA-B is out of range
  - STA-B would not be able to detect transmissions from STA-A, and the probability of collision is greatly increased
  - This is known as the Hidden Node

MAC Architecture



Courtesy: IEEE

MAC Schemes

- Distributed Coordination Function (DCF)
  - Similar to traditional legacy packet networks supporting best packet delivery of the data
  - DCF is designed for asynchronous data support
    - All users with data to transmit have an equally fair chance of accessing the network
- Point Coordination Function (PCF)
  - Based on polling that is controlled by an access point
  - Primarily designed for the transmission of delay-sensitive traffic
- Ad hoc network (DCF only) & Infrastructure network (DCF & PCF)

802.11 MAC Layer

- The MAC is concerned with rules for accessing the wireless medium
  - It is supported by underlying PHY layer
- Basic Service Set (BSS)
  - Consists of 2 or more wireless nodes or stations (STAs)
    - Recognize each other & have established communications
  - Contains an Access Point (AP)
    - Form bridges between wireless & wired LANs
    - Analogous to a base station used in cellular phone networks
    - Immobile & part of the wired network infrastructure
    - All communications between STAs or between a station & a wired network client go through the AP

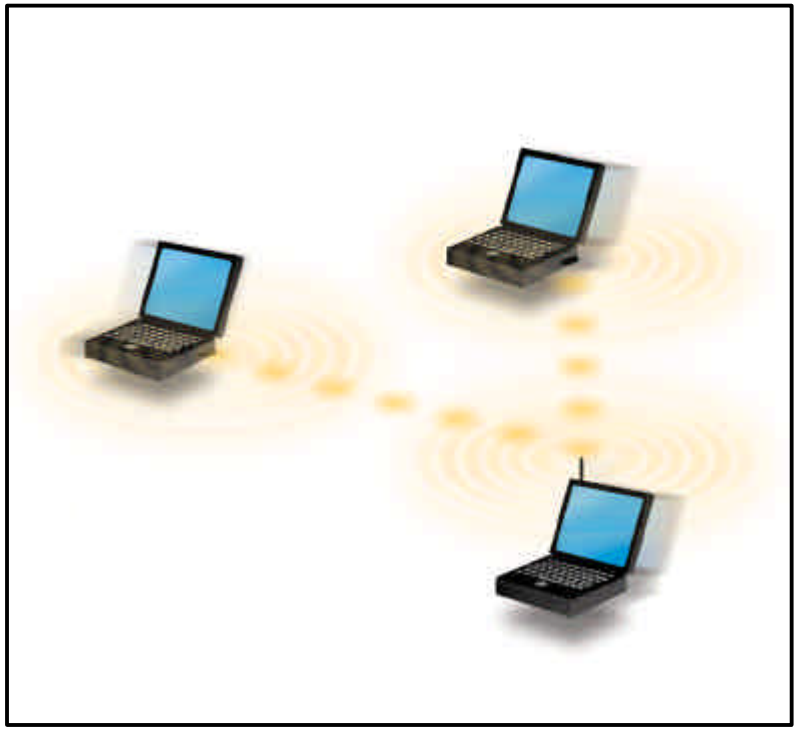
What is an Access Point?

- Wireless Hub
- Gateway for non wireless network to wired network
- Network police and policy manager
- Network management tool

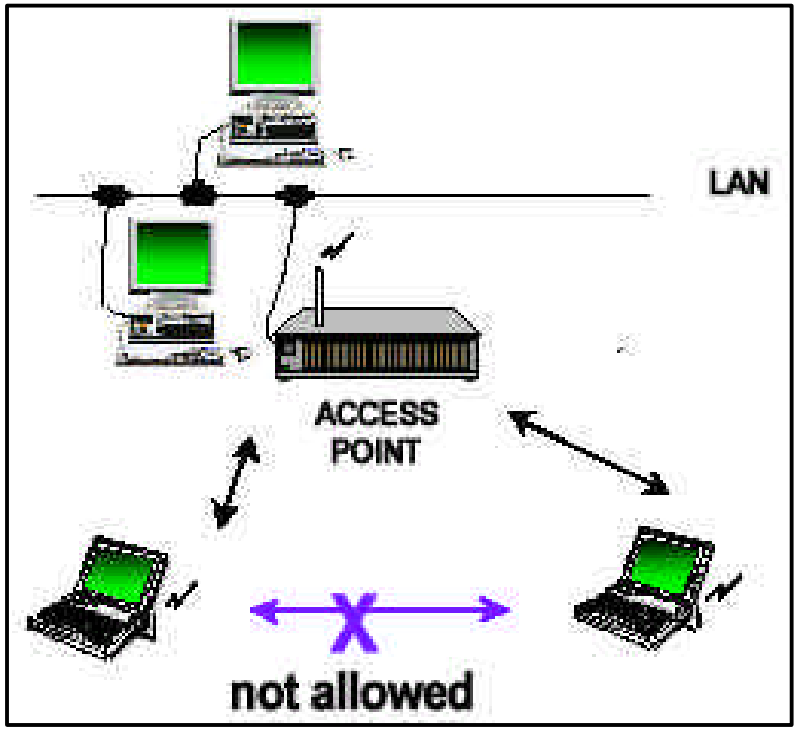
IEEE 802.11 Networking Modes

- 802.11 MAC layer has 2 defined networking architectures
  - "Ad-Hoc" Network architecture
    - Used to support mutual communication among wireless clients
    - Created spontaneously
    - Does not support access to wired networks
    - Does not need an AP to be part of the network
    - Perfect for conference room setups
  - "Infrastructure" Network architecture
    - Provides communication between wireless clients & wired network resources
    - Transition of data from wireless to wired medium is via an AP
    - Coverage area is defined by APs & associated wireless clients
      - Together all devices form a Basic Service Set (BSS)

Ad-Hoc vs. Infrastructure Networking Modes

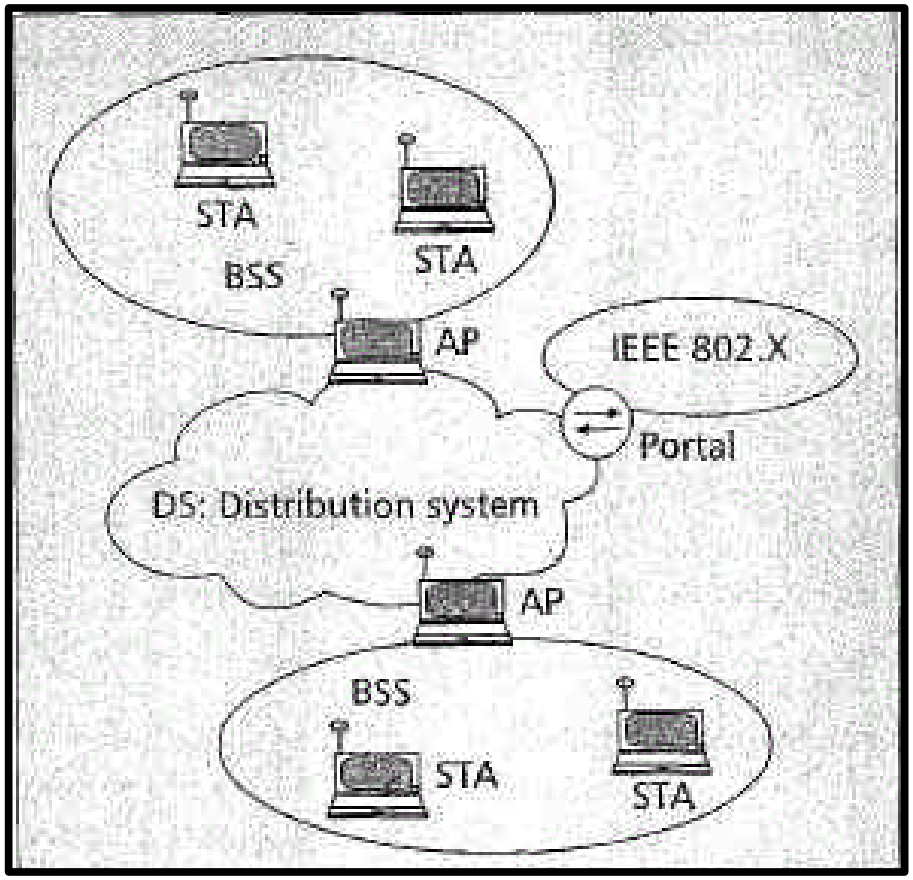


Ad Hoc Network



Infrastructure Network

Sketch of an Infrastructure Network



Courtesy: IEEE

Services Provided by MAC Layer

- Data transfer
  - Wireless clients use CSMA/CA (Carrier Sense Multiple Access with Collision Avoidance) algorithm as media access scheme
- Association
  - Service enables establishment of wireless links between wireless clients & APs in Infrastructure Networks
- Reassociation
  - Occurs when wireless client moves from one BSS to another
  - 2 adjoining BSS form an Extended Service Set (ESS)
    - Defined by common ESSID
    - If common ESSID is defined, wireless client can roam from one area to another

Services Provided by MAC Layer

- Power management
  - IEEE 802.11 supports 2 power modes at the MAC level for those applications requiring mobility under battery operation
  - Active Mode
    - Wireless client is powered to transmit & receive
  - Power Save Mode - “Sleep” mode
    - Provisions are made in the protocol for the portable stations to go to low power "sleep" mode during a time interval defined by the base station
    - Consumes less power
    - Client is unable to transmit or receive

Services Provided by MAC Layer

- Authentication
  - Process of proving client identity
  - Takes place prior to a wireless client associating with an AP
  - True Authentication
    - Use of Wired Equivalent Privacy (WEP)
    - Shared Key is configured into the AP & its wireless clients
    - Valid Shared Key allows association with AP

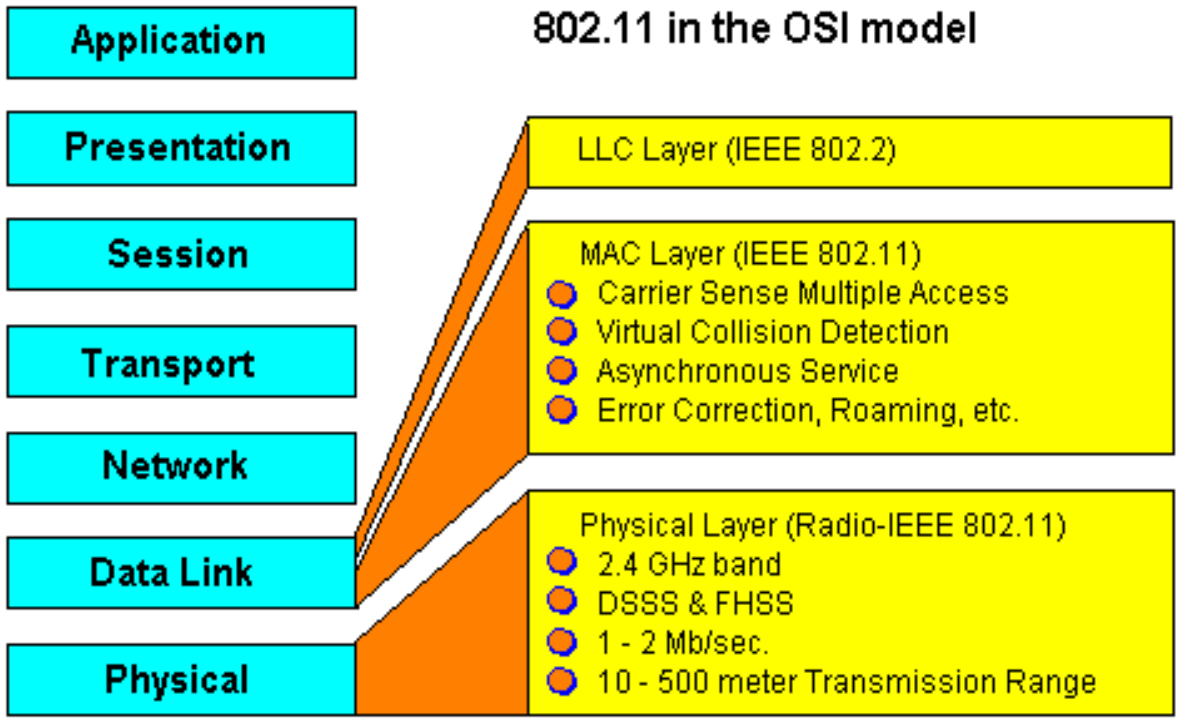
Services Provided by MAC Layer

- Security and privacy
  - Addressed in the 802.11 standard as an optional feature for those concerned about eaves dropping
    - Data is transferred “in the clear”
      - Any 802.11 device can eavesdrop on traffic that is within range
  - Data security is accomplished by a complex encryption technique know as Wired Equivalent Privacy Algorithm (WEP)
    - WEP encrypts data before it is sent wirelessly

WEP

- Protects the transmitted data over the RF medium using a 64-bit seed key & the RC4 encryption algorithm
  - Only wireless clients with the exact Shared Key can correctly decipher the data
  - The same Shared Key is used in authentication to encrypt & decrypt data
- WEP only protects the data packet information
  - It does not protect the PHY header so that other stations on the network can listen to the control data needed to manage the network
  - However, other stations cannot decrypt the data portions of the packet

IEEE 802.11 Summary



Wireless Devices Interoperability through IEEE 802.11 Spec

- Interoperability among devices
  - 3 physical layer modulation schemes (IR, DSSS, FHSS) are incompatible with each other
- Multivendor interoperability requires a standard for
  - AP-to-AP coordination for roaming
    - Standard does not specify the handoff mechanism to allow clients to roam
  - Data frame mapping
    - Standard does not state how an AP addresses data framing between wired & wireless media
  - Conformance test suite
    - Verification of device compliance with IEEE 802.11 spec needs to be specified by a conformance test suite

IEEE 802.11 WLAN Types

- IEEE 802.11 a
  - PHY layer: 5 GHz, OFDM
  - Data rate: 40 Mbps
- IEEE 802.11 b
  - PHY layer: 2.4 GHz, DSSS
  - Data rate: 11 Mbps

IEEE 802.11b Security

IEEE 802.11b

- Wireless version of the IEEE 802.3 wired Ethernet
  - Delivers a data rate of up to 11Mbps
  - Uses spread spectrum - FHSS or DSSS
  - 802.11b compliant radio frequency is around 2.4 GHz
    - Subject to national regulations & can hence vary from country to country
  - Requires equivalent encryption as IEEE 802.3
- Encryption goal - provide “Wired Equivalent Privacy”
  - Intruders should not be able to access network resources
  - Intruders should not capture WLAN traffic (eavesdropping)
  - Worldwide usable

Simply - Here's How it Works

- Authentication
  - A, to sign a message, does a computation involving both her private key and the message itself; the output is called the digital signature and is attached to the message, which is then sent
  - B, to verify the signature, does some computation involving the message, the purported signature, and A's public key
  - If the results properly hold in a simple mathematical relation, the signature is verified as genuine; otherwise, the signature may be fraudulent or the message altered, & they are discarded

Simply - Here's How it Works

- Encryption
  - When A wishes to send a message to B, she looks up B's public key in a directory, uses it to encrypt the message and sends it off
  - B then uses his private key to decrypt the message and read it
  - No one listening in can decrypt the message
  - Anyone can send an encrypted message to B but only B can read it
  - Clearly, one requirement is that no one can figure out the private key from the corresponding public key.

Data Encryption
Secure Transmission of Information

- Physical layer
  - Physical security of data transmission is gained by using spread spectrum technology which makes it less vulnerable to interference
- MAC (Medium Access Control) layer
  - Encryption algorithm is called Wired Equivalent Privacy (WEP)
    - 2 part process - WEP encrypts the plaintext data (RC4) & protects against unauthorized data modification (CRC-32)
    - WEP is only supplied between stations & not on an end-to-end basis

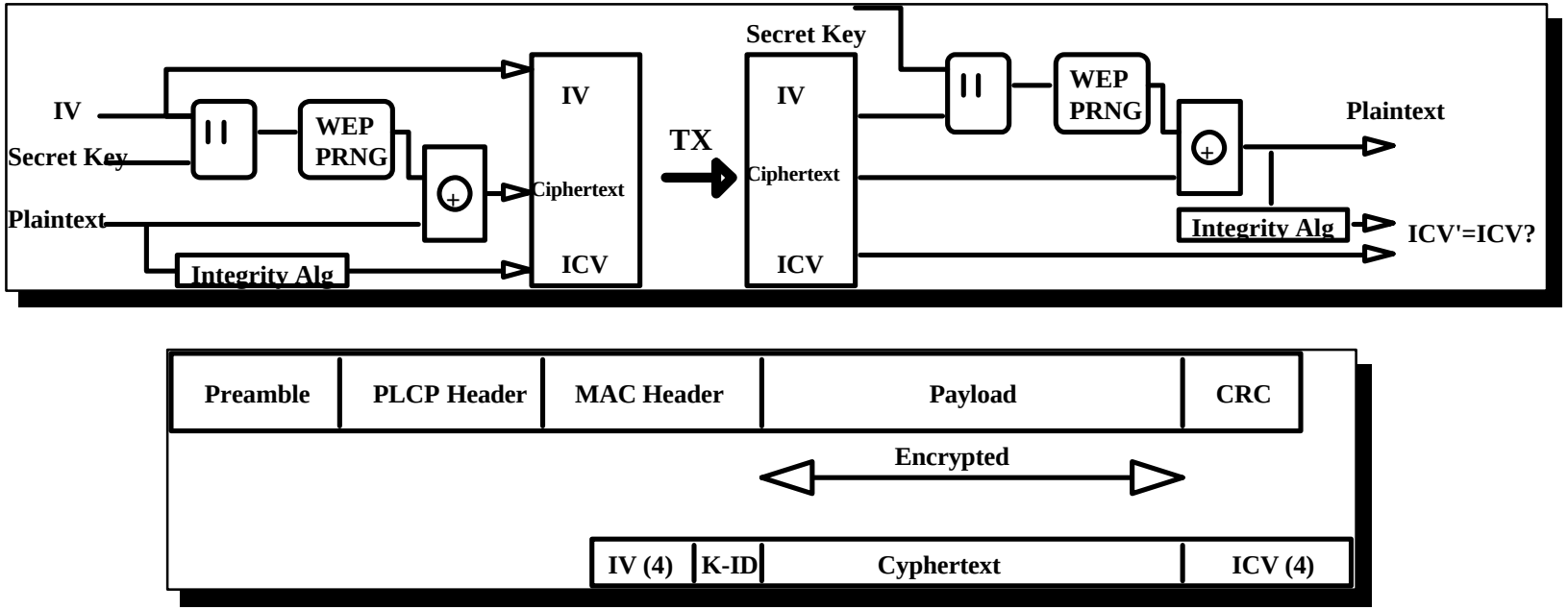
MAC Authentication Mechanism

- Aids in access control
  - Performed by assigning a ESSID (Extended Service Set ID) to each Access Point (AP) in the network
- The network does not provide anonymity
  - The source & destination information is visible in the frames despite of the optional encryption
  - The WEP only encrypts the data field of a frame while leaving headers unencrypted
    - Gives an eavesdropper the ability to gather information about the usage of APs & work routines in a building using WLANs
- Has provisions for “OPEN”, “Shared Key” or proprietary authentication extensions

WEP Privacy Mechanism

- Provides encryption
  - Uses RSA Data Security Inc.'s 40-bit RC4 algorithm for encrypting data (plain text) contained in the frames
    - PRNG algorithm & output of the generator (key) is XORed with the data stream (stream cipher)
    - Based on 40-bit secret key & has a 24 bit initialization vector that is sent with the data (total key size is 64-bit)
    - 128-bit RC4 keys can be used
      - Using a 40-bit symmetric cipher is not secure because its key space so small that a brute-force attack is feasible
- Provides protection against unauthorized data modification
  - Integrity algorithm (CRC-32) operates on the the plaintext to produce the integrity check value
  - Produces the ciphertext

WEP Privacy Mechanism

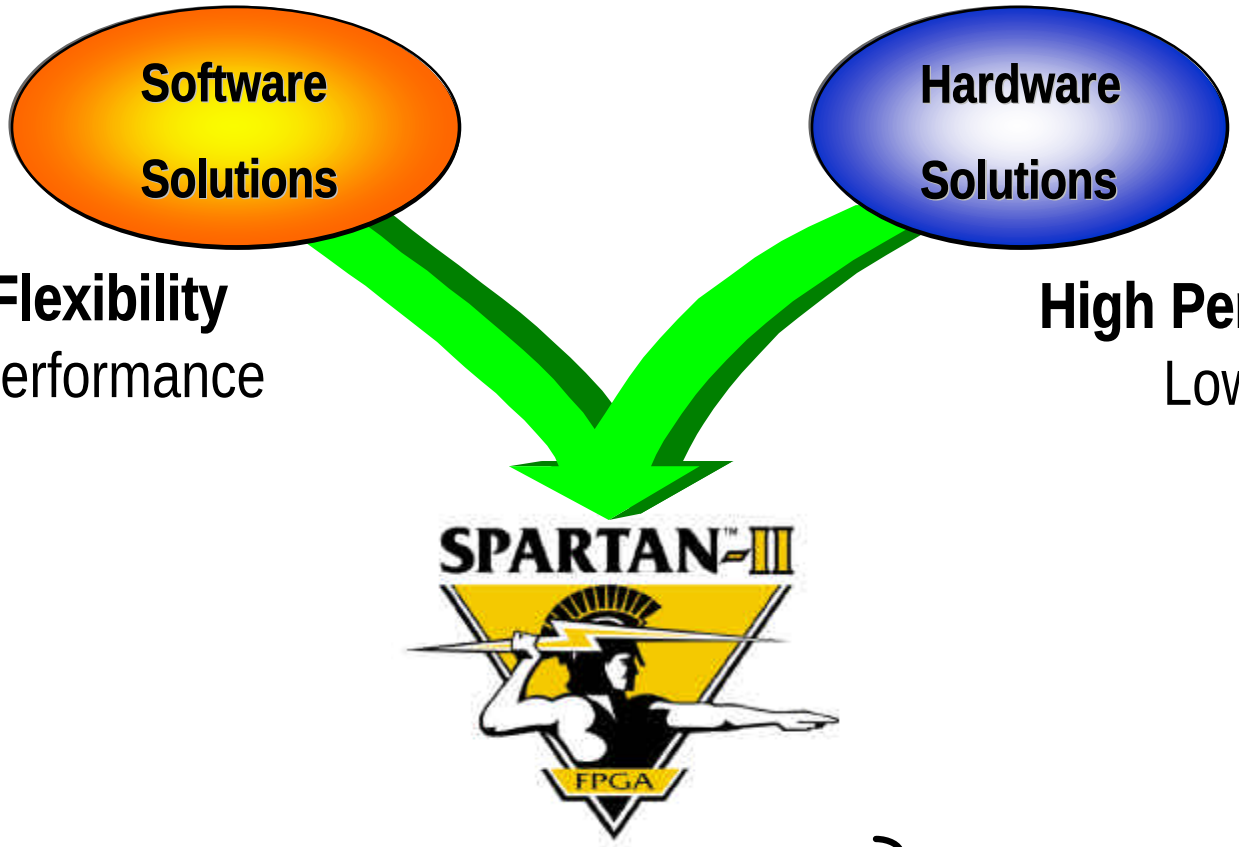


- WEP bit in Frame Control Field indicates WEP used
  - Each frame can have a new IV, or IV can be reused for a limited time
  - If integrity check fails then frame is ACKed but discarded
- Limited for Station-to-Station traffic, so not “end to end”
  - Embedded in the MAC entity

802.11 Selected WEP Protocol Because It Is

- Reasonably strong
  - Brute-force attack is difficult because every frame is sent with an Initialization vector which restarts the PRNG for each frame
- Self synchronizing
  - The algorithm re-synchronizes for each message to work in a connection-less environment, where packets may get lost
- Computationally efficient
  - Can be implemented in hardware & software
- Exportable outside the US
- Optional - Defined as an optional functionality of the MAC

Spartan-II Advantages Over Hardware & Software Solutions



Agenda

- Introduction to wireless home networking
- Wireless LAN technology
- Consortiums
- IEEE 802.11
- HiperLAN & HiperLAN2
- Products & solutions available in the industry today
- Xilinx solutions in wireless LAN products
- Summary

HiperLAN & HiperLAN2

High Performance Radio LAN

XILINX®

Backgrounder

- ETSI (European Telecommunications Standards Institute)
  - Developing HiperLAN standards as part of an effort called BRAN (Broadband Radio Access Network)
  - Effort includes 4 standards
    - HiperLAN1
    - HiperLAN2
    - HiperLink
      - Designed for indoor radio backbones
    - HiperAccess
      - Designed for fixed outdoor use to provide access to a wired infrastructure

Backgrounder

- Both HiperLAN standards are approved standards for European spectrum
- HiperLAN2 has a key advantage over IEEE 802.11a
  - 802.11a products may not be usable in Europe

End User Applications

- Office
  - HiperLAN2 benefits companies with a flexible workforce
  - Employees can transfer their laptop computers from one project to another
  - Allows continuous exchange of large amounts of information between project members and the company server
  - It is also possible to connect several desktop computers & video projectors via HiperLAN2

End User Applications

- Construction
  - With HiperLAN2 installed, workers on a construction site can use laptops to collect blue prints, order materials & communicate with experts
  - By sending short video sequences via the integrated camera to an expert in real time, a problem can be looked at, discussed & solved , using the high quality audio function
  - The broadcast function also means that everyone working on site can be contacted with any information and that creates a more efficient on-site operation

End User Applications

- Home
  - Domestic electronics like TVs, cameras, stereo equipment & PCs can all be interconnected by HiperLAN2 using small H2 modules which automatically establish connectivity
  - HiperLAN2 allows multimedia equipment to be intelligently controlled from any computing device in the home without the need for network cables

End User Applications

- Airport
  - HiperLAN2 enables travelers and employees to work while on the move
    - Gives them access to the company network, Internet & the ability to make and receive multimedia calls
  - Aircraft Engineers
    - Using customized software can gain access to information from databases & get in touch with experts on site

End User Applications

- University
  - HiperLAN2 benefits both students and lecturers, allowing wireless access to the university Internet
  - Covering the entire campus, students can access information, such as videotaped lectures and remote supervision transmitted by their lecturer
  - Two-way communication can take place between students and lecturers through laptops

5GHz vs. 2.4GHz

The Better Spectrum Band for Wireless LANs

- 2.4GHz Band
  - Most LANs operate in this unlicensed band
  - Several limitations
    - Only 80MHz wide
    - Mandates use of spread spectrum technology
    - WLAN users must not interfere with primary license holders
- 5GHz Band
  - Developed after recognition the limitations of 2.4GHz band
  - Licensing authorities around the world have allocated large blocks of spectrum in the 5GHz band
  - Broad blocks of spectrum & lenient operating rules enable high-speed operation by large numbers of users

HiperLAN1

- Next generation, high-speed wireless LAN technology
- Standard is complete
  - Leading wireless LAN vendor Proxim is now delivering products based on it
- Offers the fastest route to market for a high-speed wireless LAN technology while minimizing the complexity of the radio technology

HiperLAN1

- Uses Gaussian Minimum Shift Keying (GMSK)
  - Well understood
  - Broadly used in GSM (Global System for Mobile Communications) cellular networks & CDPD
- Throughput up to 25Mbps

HiperLAN2

- Most sophisticated (& technically challenging) wireless LAN technology so far defined
  - Uses a new type of radio technology called Orthogonal Frequency Division Multiplexing (OFDM)
- Spec will be completed in year 2000
  - Products will not appear till 2001
- Is not the only standard deployed in this class
  - HiperLAN1 products will precede HiperLAN2
  - IEEE 802.11a will offer comparable performance
    - IEEE 802.11a & HiperLAN2 have the same PHY layer
      - Allows sharing components & cost reduction

HiperLAN2 Global Forum

- Launched in September 1999
  - Founded by Bosch, Dell, Ericsson, Nokia, Telia & TI
  - Strong industry backing
    - Alcatel, Cambridge Silicon Radio, Canon, Lucent, Intersil, Panasonic, Mitsubishi, Motorola, National Semiconductor, NTT, Philips, Samsung, Siemens, Sony, Silicon Wave, Toshiba
- Mission
  - Drive the adoption of HiperLAN2 as the global broadband wireless technology in 5GHz band
  - Providing untethered connectivity for mobile devices in corporate, public & home environments
- www.hiperlan2.com

Compelling Features of HiperLAN2

- Mobility
- High speed transmission
  - Raw over-the-air rate is 54Mbps at the PHY layer
  - Sustained throughput for applications is 20Mbps
- QoS
  - Connection-oriented network
    - Data is transmitted on connections between the MT (mobile terminal) and the AP that have been established prior to the transmission
    - Straight forward to implement QoS support
  - Important for applications like video & voice

HiperLAN2 Architecture

- Network and application independence
  - HiperLAN2 protocol stack has a flexible architecture for easy adaptation & integration with a variety of fixed network
  - Provides connections to multiple network infrastructures
  - Includes Ethernet, IP, ATM, PPP, 3G cellular networks
- Automatic frequency management
  - Like cellular networks such as GSM there is no need for manual frequency planning
  - APs have a built-in support for automatically selecting appropriate radio channels for transmission within each AP's coverage area
  - Simplifies deployment

HiperLAN2 Architecture

- Security
  - Authentication & Encryption
    - AP & MT can authenticate each other to ensure authorized network access
    - Authentication relies on supporting functions such as directory service
    - Encryption protects the user traffic on an established connection against eaves-dropping & man-in-middle attacks

HiperLAN2 Architecture

- Power save
  - MT may at anytime request the AP to enter a low power state and provide a sleep period
  - At the expiration of the negotiated sleep period the MT searches for any wake up indication from the AP
  - In the absence of a wake up indication the MT reverts back to its low power state for the next sleep period
  - The AP defers any pending data to an MT until the corresponding sleep period expires
  - Different sleep periods are supported to allow either short latency requirement or low power requirement

HiperLAN2 Technology

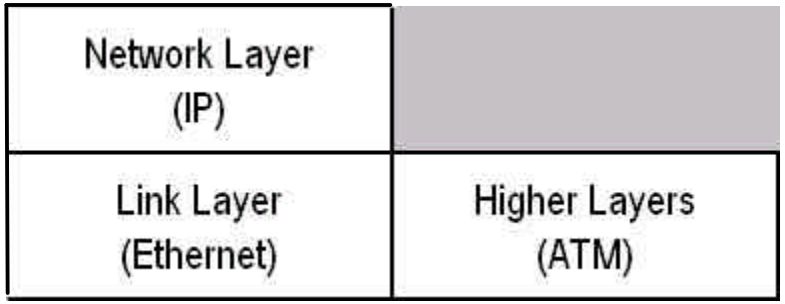
- Connects mobile terminals to access points
  - To bridge traffic to wired networks
- Also allows mobile nodes to communicate directly with each other
- Seamless extension to other networks
  - Wired network nodes see HiperLAN2 nodes as other network nodes
  - All common networking protocols at layer 3 (IP, IPX & AppleTalk) will operate over HiperLAN2
    - Permits network-based applications to operate

Network Topology

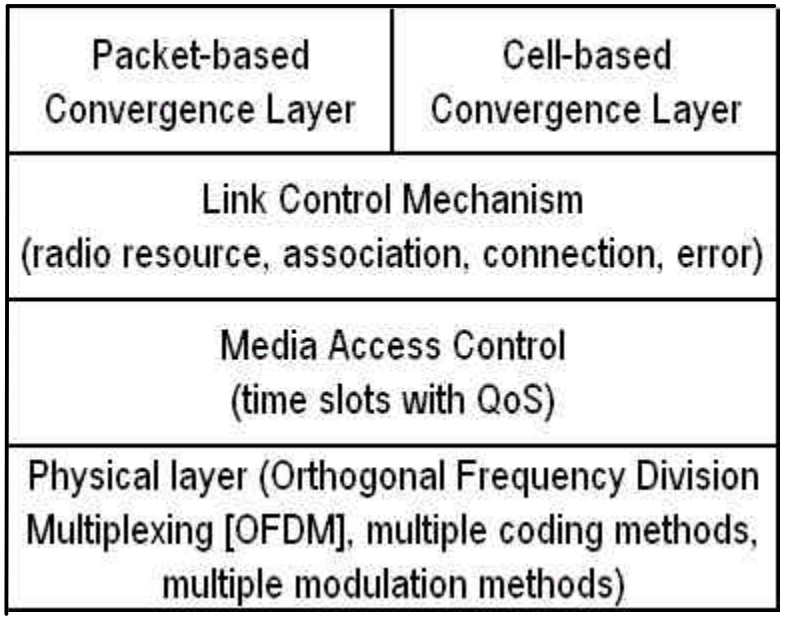
- HiperLAN2 defines a PHY layer & a Data-link layer
- Above these layers is a Convergence layer
  - Accepts packets or cells from existing networking systems & formats them for delivery over the wireless medium

HiperLAN2 Protocols

Network Infrastructure



HiperLAN2



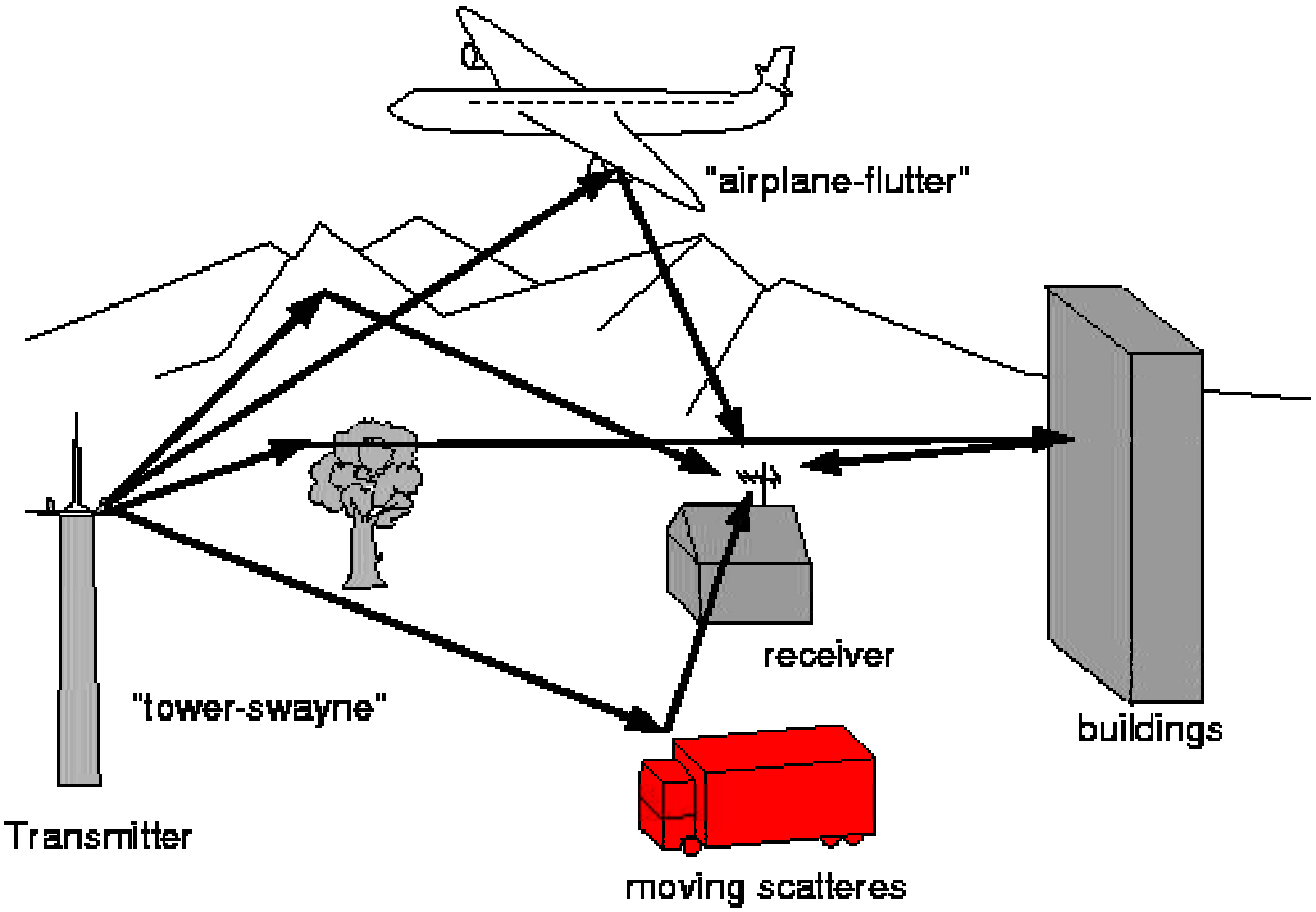
Orthogonal Frequency Division Multiplexing - OFDM

- First time being used as a WLAN standard
  - Used in wireless broadcast application for European Digital Audio Broadcast (DAB)
  - Discrete Multitone (DMT) for ADSL (Asymmetric Digital Subscriber Lines)
- Extremely effective in a time-dispersive environments
  - Signals can take many paths to reach their destinations
  - Results in variable time delays
  - At high data rates these time delays can reach a significant proportion of the transmitted symbol (a modulated waveform)
    - Results in one symbol interfering with the next
    - OFDM is the answer to this “intersymbol interference”

Introducing OFDM Technology

- Allows transmission over high data rates over extremely hostile channels at comparable low complexity
- Issue - data transmission over multipath channels
  - Different from satellite communication where there is one single direct path from transmitter to receiver
  - In the classical terrestrial broadcasting scenario we have to deal with a multipath channel
    - The transmitted signal arrives at the receiver in various paths of different length
    - Since multiple versions of the signal interfere with each other (inter symbol interference (ISI)) it becomes very hard to extract the original information

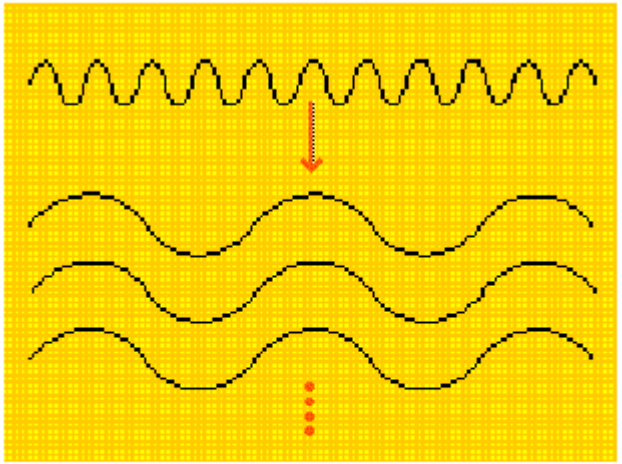
Multipath Transmission in a Broadcasting Application



OFDM - Technology

- Special method of multi-carrier modulation
  - Like all wireless transmission schemes, OFDM encodes data onto a radio frequency (RF) signal
  - OFDM transmits multiple high data rate signals concurrently on different frequencies
  - The channel spectrum is passed into a number of independent non-selective frequency sub-channels
    - These subchannels are used for one transmission link between the AP and MTs

OFDM



Single high-frequency carrier is replaced by multiple subcarriers, each operating at a significantly lower frequency

- Division of a single high-frequency radio channel into multiple subcarriers
  - Data is transmitted in parallel bit streams on them
    - Each one of these bit streams is modulated on a separate subcarrier
  - Aggregate throughput is the same but the data rate on each subcarrier is much lower
    - Makes each symbol longer
    - Practically eliminates the effect of the variable time delays

OFDM & Synchronization

- HiperLAN2 products will cost more than lower-speed alternatives
  - OFDM demands extremely linear power amplifiers
    - Increase the cost of the radio
- Spectral allocation for Europe
  - HiperLAN2 channels will be spaced 20MHz apart
    - Total of 19 channels
  - Each channel will be divided into 52 subcarriers
    - 48 data carriers & 4 as pilots to provide synchronization
  - Synchronization enables coherent in-phase demodulation
    - Through DSP, subchannels are divided through mathematical processing rather than in the analog domain

OFDM in Practice

- OFDM is efficiently realized by using effective signal processing, fast-fourier transforms (FFT) in the transmitter & receiver
  - Significantly reduces the amount of hardware required compared to earlier FDM-systems
- OFDM requires a properly designed system
  - Specially important is the design of frequency synchronization & power amplifier back-off in the receiver

Advantages of OFDM

- OFDM results in a very efficient use of bandwidth
  - Provides robust communications in the presence of noise, intentional or unintentional interference & reflected signals that degrade radio communications
  - Conventional single carrier transmission schemes like AM/FM send only one signal at a time using one RF
- Lesser utilization of hardware
  - Effective signal processing, FFT

Advantages of OFDM

- Increased spectral efficiency
  - That is, more bps/Hz than conventional transmission schemes
  - Spectrally efficient because the spectrum can be made to look like a rectangular window
    - Because the subcarriers are packed maximally close together
    - All frequencies are utilized similarly
- Robustness against the adverse effects of multipath propagation with respect to intersymbol interference
- OFDM is less sensitive to timing errors
  - A timing error is simply translated to a phase offset in the frequency domain

OFDM Compared to Other PHY Technologies

- The 3 RF technologies available to solve the challenge of increasing the speed of wireless data/Internet networking
  - Narrow band microwave
  - Spread spectrum
    - Frequency Hopping Spread Spectrum
    - Direct Sequence Spread Spectrum
  - OFDM

OFDM Compared to Narrowband Microwave

- Narrow band systems
  - Power to transmit the data is increased to overcome the noise
    - This improves the performance of the transmission, but interferes with other signals that are being sent by other users of the band, causing data errors for others
  - Sensitive to multipath interference
    - In this your own signal is reflected off another object and arrives late at the destination, scrambling the original signal
    - This requires on-going tuning and adjustment using specific hardware which means an increased system cost

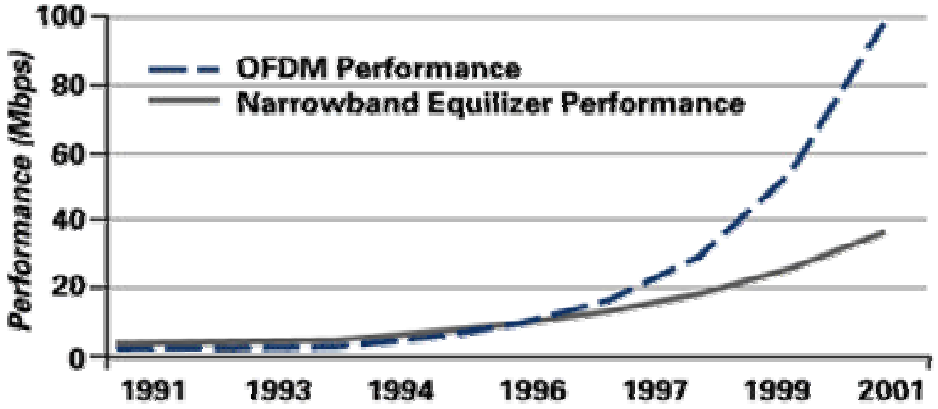
OFDM Compared to Spread Spectrum

- Spread spectrum technology
  - Uses much more bandwidth than is absolutely required to send signals, but this allows it to overcome noise & multipath problems
  - As the amount of data increases, the bandwidth required rises
    - The best systems to date deliver 11 Mbps and use 22MHz of spectrum.
    - That translates to less than 44 Mbps maximum if one used the entire 2.4 GHz license-exempt band
    - The best possible speed achievable is approximately 15 Mbps in 22 MHz, which means that spread spectrum technology is approaching its limits in speed

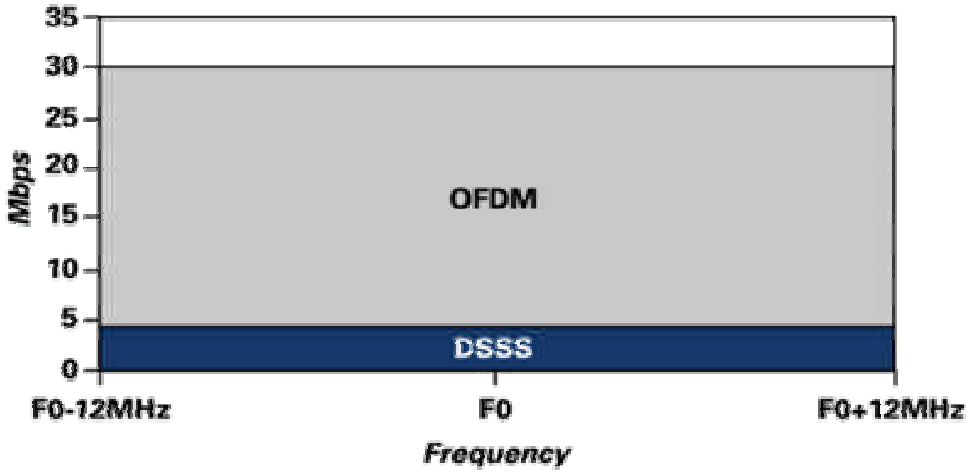
OFDM Compared to Other PHY Technologies

- OFDM technology
  - Breaks one high-speed data signal into tens or hundreds of lower speed signals, which are all transmitted in parallel
    - This creates a system highly tolerant to noise and multipath &, at the same time, is very efficient in its use of bandwidth
  - Noise and multipath immunity allow for wide-area, multipoint coverage, and the efficient use of bandwidth allows for many more high-speed channels within a frequency band
- Therefore, the main difficulties in narrow band and spread spectrum are overcome by OFDM

OFDM Compared to Other PHY Technologies



OFDM
vs.
Narrowband



OFDM
vs.
DSSS

Source: Wi-LAN

OFDM is Gaining Popularity

- OFDM is a very efficient technology, but it was proven to be difficult to implement until now
  - Recent advances in DSPs now permit OFDM systems to be cost-effectively constructed creating a renewed interest
- The digital audio and terrestrial digital video broadcasting standards are based on OFDM
- In 1998, the IEEE 802.11a approved the use OFDM
  - For its high-speed (6 to 54 Mbps) extension to the 802.11 WLAN standard
- ETSI is using OFDM for the ETSI BRAN HiperLAN2 standard

Advantages of Wideband OFDM (W-OFDM)

- Great performance against multipath, through a simple division by the channel frequency response
- Enhanced equalization of radio distortions, through a division by the channel frequency response that includes the radio distortion
- Easy inclusion and optimal exploitation of forward error correcting codes, like Reed-Solomon, ensuring the integrity of transmitted data
  - This includes the ability to recover the symbols, even if some carriers are totally absent
- Less sensitive to carrier offset

Advantages of W-OFDM

- More amenable to erasures of errors in the forward error corrector
  - Improves the bit error rate performance by over an order of magnitude
  - The positions of the errors can easily be determined from the estimated channel frequency response
- The whitening process reduces the peak to average ratio, thus reducing linearity requirement of the power amplifiers
- The group delay of the frequency response can be used to deliver an estimate of the propagation time between the transmitter and receiver

PHY Layer

Includes Data Encoding & Subchannel Modulation Type

- OFDM does not fully describe the PHY layer
- Encoding involves serial sequencing of data & FEC
  - Lower speed wireless LANs do not employ FEC
  - HiperLAN2 provides multiple levels
    - Each capable of protecting against a certain % of bit errors
- HiperLAN2 employs multiple types of modulation
  - Dynamic adaptation of the FEC & modulation to varying conditions
  - Allows data transmission at
    - Higher data rates with a strong signal relative to noise
    - Lower throughputs under adverse conditions

H2 - Data-link Layer

- Data-link layer constitutes the logical link between an AP and the MTs
  - Data-link sub layers include MAC protocol, Error Control (EC) protocol, Radio-Link Control (RLC) protocol
- Data-link layer in HiperLAN2 is connection-oriented differentiating it from other wireless LANs
  - Before a mobile terminal transmits data the Data-link layer communicates with the AP in the signaling plane to set-up a temporary connection
    - This allows the negotiation of QoS parameters like bandwidth & delay requirements
    - Assures that other terminals will not interfere with subsequent transmissions

H2 - Data-link Layer

- HiperLAN2 contrasts with MTs conforming to IEEE 802.11 std.
  - IEEE 802.11
    - They communicate when the radio channel becomes available
    - May experience packet collisions from other terminals
    - IEEE 802.11 does provide separate mechanism for synchronous applications like voice

H2 - QoS

- QoS parameters include
  - Bandwidth, bit error rate, latency, jitter
- HiperLAN2 implements QoS through time slots
  - Original request by a mobile terminal made to send data uses specific time slots allocated for random access
  - Collisions from other mobile terminals can occur in this random-access channel
    - Since messages are brief, this is not a problem

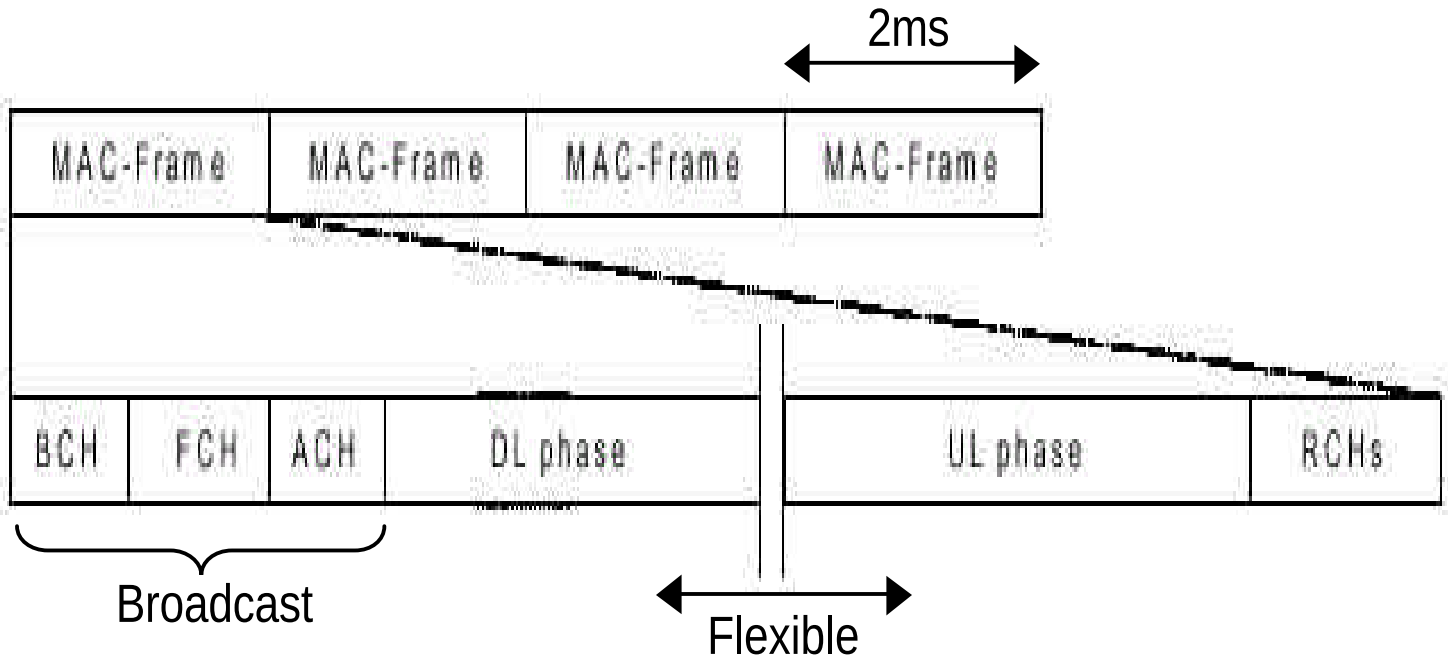
H2 - Data-Link Layer

- Transport channels
  - Access point grants access by allocating specific time slots for a specific duration
  - Mobile terminal then sends data without interruption from other mobile terminals operating on that frequency
  - Control channel provides feedback to the sender
    - Indicates whether data was received in error & if it needs to be retransmitted

H2 - MAC Protocol

- MAC protocol
  - Used for access to the medium with the resulting transmission of data onto that medium
  - Control is centralized to the AP which informs the MTs
    - It is at this point that the MAC frame is allowed to transmit data
- MAC frame in H2
  - Air interface is time-division duplex (TDD) & dynamic time-division multiple access (TDMA)
    - Time slotted structure of the medium allows for simultaneous communication in both downlink and uplink within the same time frame
  - MAC frame forms the interface between Data link & PHY layer

H2 - Frame Structure



- Centrally controlled TDMA/TDM with TDD
- Packet sizes 54 bytes (data) & 9 bytes (control)

H2 - Error Control Protocol

- Selective repeat (SR) ARQ is the Error Control (EC) mechanism
  - Increases reliability over the radio link
  - Detects bit errors and and retransmits U-PDU(s) if such errors occur

H2 - Convergence Layer (CL)

- Exists above the Data-link layer & has 2 main functions
  - Adaptive service requests
    - Responds to service requests from higher layers to the service offered by the data link layer
  - To convert the higher layer packets (SDUs) with variable or possibly fixed size that is used within the data link layer
    - Formats data (padding, segmentation & reassembly function)
- Generic architecture of the CL makes HiperLAN2 suitable for a diversity of fixed networks
  - E.g., Ethernet, IP, ATM, UMTS, etc.
- 2 different types of defined CLs: packet-based (Ethernet) & cell-based (ATM) communication

H2 - Radio Network Functions

- H2 standard defines measurement & signaling to support a number of radio network functions
  - Dynamic frequency selection
  - Link adaptation
  - Antennas
  - Handover
  - Power Control

HiperLAN2 - AFA

- Comes with Automatic Frequency Allocation (AFA)
  - To provide continuous coverage access points need to have overlapping coverage areas
  - Coverage extends 30m indoors & 150m in unobstructed environments
  - APs monitor the HiperLAN radio channels & automatically selects an unused channel
    - Eliminates the need for frequency planning
    - Makes deployment relatively straightforward

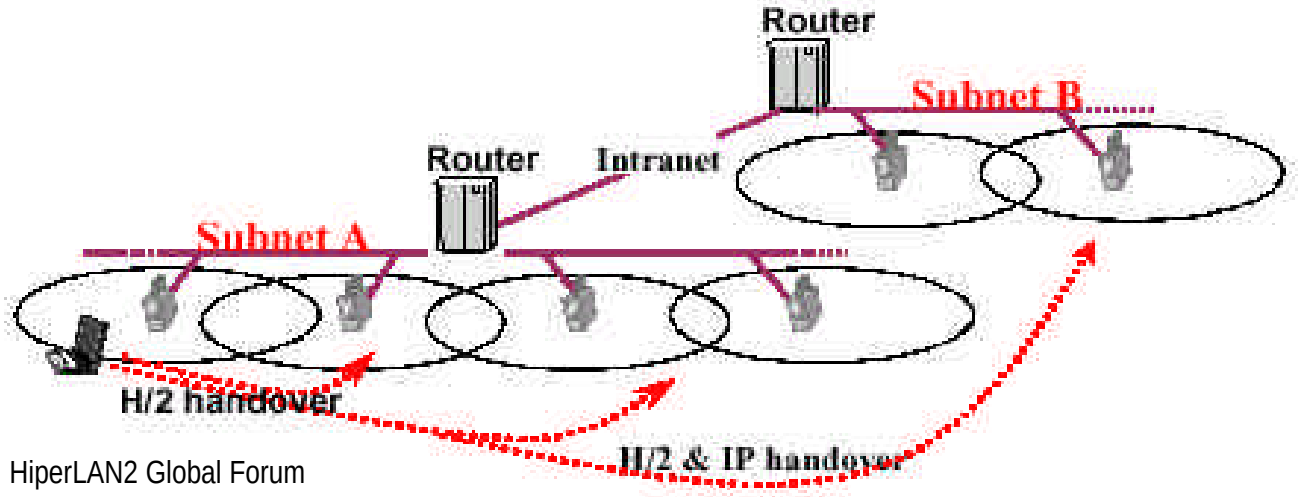
HiperLAN2 - Roaming

- Mobile terminal roams from coverage area of one AP to another
  - Initiates handoff to the new access point after detecting a better signal on another radio channel
  - New AP obtains details of the mobile terminal's connection from old AP
    - Allows communication to continue smoothly

HiperLAN2 - Security Mechanism

- Mobile terminal creates a secure communication session (association) with the AP
  - First using Diffie Hellman key exchange to negotiate a secret session key
  - Then mutual authentication process via a secret key or public hey if a PKI is available
  - Data traffic is encrypted using DES or Triple DES
- Communication over HiperLAN2 should be as secure as wired LANs

H2 - Example Applications



Source: HiperLAN2 Global Forum

- Corporate LAN
  - Example of a corporate network built around ethernet LAN and IP routers
  - A H2 network is used as the last segment between the MTs and the network/LAN
  - The H2 network supports mobility within the same LAN/subnet
  - Moving between subnets implies IP mobility which must be taken care of on a layer above H2

H2 - Example Applications

- Hot spots
  - H2 networks can be deployed at hot spot areas, enabling an easy way of offering remote access and Internet services to business people
    - E.g. airports, hotels, etc.
  - An access server to which the H2 network is connected can route a connection request for a point-to-point connection (PPP) over a tunnel either to to the corporate network (via a preferred ISP) or perhaps to an ISP for Internet access

H2 - Example Applications

- Access to 3 rd generation cellular network
  - HiperLAN/2 can be used as an alternative access technology to a 3 rd generation cellular network
  - One may think of the possibility to cover hot spots and city areas with HiperLAN/2 and the wide area with W-CDMA technology
    - In this way, a user can benefit from a high-performance network wherever it is feasible to deploy HiperLAN/2 and use W-CDMA elsewhere
    - The core network sees to that the user is automatically and seamlessly handed over between the two types of access networks as the user moves between them

H2 - Example Applications

- Home network
  - The use of this technology in a home environment to create a wireless infrastructure for home devices
    - E.g. home PCs, VCRs, cameras, printers, etc.
  - The high throughput and QoS features of HiperLAN/2 support the transmission of video streams in conjunction with the datacom applications
  - The AP may in this case include an “uplink” to the public network - “Residential Gateway”
    - E.g. ADSL or cable modem

HiperLAN2 - Features Summary

- PHY layer
  - OFDM modulation, variable bit rate
  - FEC error control
- Data-link layer
  - QoS via dynamic fixed time slots (within MAC)
  - ARQ (within EC)
  - Dynamic frequency selection
  - Power control
  - Cellular handover
  - Public & private key encryption
- Convergence layer
  - Supports both cell & packet based networks

HiperLAN2 - Summary

- Lots of bandwidth, up to 54Mbps
- QoS
- Plug & play radio network
- Service negotiation
- Security, authentication & encryption
- Spectrum availability
- Scalable
- Generic architecture supporting Ethernet, Firewire, ATM, PPP, 3G, etc.
- Considerably cheap

IEEE 802.11 vs. HiperLAN2

Comparison - 802.11 vs. HiperLAN2

Characteristic	802.11	802.11b	802.11a	HiperLAN2
Spectrum	2.4 GHz	2.4 GHz	2.4 GHz	5 GHz
Maximum physical rate (apprx.)	2 Mbps	11 Mbps	54 Mbps	54 Mbps
Maximum data rate, layer 3 (approx.)	1.2 Mbps	5 Mbps	32 Mbps	32 Mbps
Medium access control/Media sharing	Carrier sense - CSMA/CA	CSMA/CA		Central resource control/TDMA/TDD
Connectivity	Connection-less	Connection-less	Connection-less	Connection-oriented
Multicast	Yes	Yes	Yes	Yes
QoS support	PCF	PCF	PCF	ATM/802.1p/RSVP/DiffServ (full control)
Frequency selection	Frequency-hopping or DSSS	DSSS	Single carrier	Single carrier with Dynamic Frequency Selection
Authentication	No	No	No	NAI/IEEE address/X.509
Encryption	40-bit RC4	40-bit RC4	40-bit RC4	DES, Triple-DES
Handover support	No	No	No	No
Fixed network support	Ethernet	Ethernet	Ethernet	Ethernet, IP, ATM, UMTS, Firewire, PPP
Management	802.11 MIB	802.11 MIB	802.11 MIB	HiperLAN/2 MIB
Radio link quality control	No	No	No	Link adaptation

PCF - Point Control Function; Concept defined in 802.11 to allow certain time slots being allocated for real-time

Agenda

- Introduction to wireless home networking
- Wireless LAN technology
- Consortiums
- IEEE 802.11
- HiperLAN & HiperLAN2
- Products & solutions available in the industry today
- Xilinx solutions in wireless LAN products
- Summary

Companies & Products

Silicon Vendors & Products

Wireless LAN Vendors/Equipment Manufacturers & Products

Silicon Vendors

- Intersil
  - Harris Semiconductor's division
  - Most heavily invested chipmaker in WLANs today
    - 22 OEMs currently ship PRISM-based WLAN products
  - Along with the chipset provides software, reference designs, manufacturing information & personnel
  - PRISM II Chipset (DSSS)
- Atheros Communications, Inc
  - HiperLAN2 5 GHz products

Silicon Vendors

- Netwave
  - Acquired by Bay Network/Nortel Networks in June 1998
  - Netwave has been active in the WLAN market since 1992
  - AirSurfer product line includes FH & DS WLANs
- Raytheon
  - High radio expertise
  - Raylink 2.4GHz FH WLAN
    - High performance (2Mbps, 500ft range)
    - Low power consumption

Silicon Vendors

- Intermec
  - Proxim includes the radios for Intermec's 2.4GHz WLANs
- RadioLAN
  - Cisco owns a minority share
  - Only RF vendor that offers 10Mbps WLAN
  - CampusLINK
    - Operates at 5.8GHz & has line-of-sight at 1,000 feet

Silicon Vendors

- RDC
- Wave Access
- Airoptics
- LCI
- Proteon

Equipment Manufacturers

- Compaq
  - WL100 11 Mbps Wireless LAN PC Card
  - WL400 11 Mbps Wireless LAN Hardware Access Point
  - WL200 11 Mbps Wireless LAN PCI Card
  - WL300 11 Mbps Wireless LAN Software Access Point
- 3Com
  - AirConnect wireless LAN Access Point
  - AirConnect wireless LAN PC Card

Equipment Manufacturers

- Nokia
  - A020 Wireless LAN Access Point (DSSS, IEEE 802.11, Enterprises)
  - A021 Wireless LAN Access Point (DSSS, IEEE 802.11, SOHO)
- Proxim
  - Makes adapters, access points, bridges
  - RangeLAN2 7401/7402 PC Card for laptops
  - RangeLAN802 8401/02 PC Card for laptops (FH)
  - RangeLAN2 7510/20/21 Ethernet Access Point (FH)
  - RangeLAN802 8520/21 Access Point
  - RangeLink products

Equipment Manufacturers

- Aironet/Cisco
  - Makes adapters, access points, bridges
  - PC4500 (PC Card) Direct Sequence
  - PC3500 (PC Card) Frequency Hopping
  - AP4500 (Ethernet) Direct Sequence Access Point
  - AP4500 (Token Ring) Frequency Hopping Access Point
  - AP3500 (Ethernet) Frequency Hopping
  - AP3500 (Token Ring) Frequency Hopping
- Lucent
  - WaveLAN IEEE PC Card (DS)
  - WaveLAN IEEE ISA Card (DS)
  - WavePoint2 (DS) access point

Equipment Manufacturers

- Symbol Technologies
  - Makes adapters, access points, bridges
  - Spectrum24 High Rate (11Mbps) 802.11b Wireless LAN
    - Ethernet Access Point 4111 - Wireless bridge between wired LANs and mobile computing devices
    - LA 4111 PC Card
    - LA 4113 PCI Card
  - Spectrum24 2Mbps 802.11 Wireless LAN
    - AP2410 Ethernet Access Point
    - AP2412 Token Ring Access Point
    - LA 2400 WLAN PC Card
    - LA 2470 ISA Wireless LAN Adapter
    - Spectrum24 SB 2401 Serial & EB 2401 Ethernet Bridges

Equipment Manufacturers

- Netwave
  - AirSurfer Pro PC card (DS)
  - AirSurfer Pro access point (DS)
  - AirSurfer Plus PC card (FH)
  - AirSurfer Plus access point (FH)
- Raytheon
  - Makes adapters, access points
  - Raylink PC Card (FH)
  - Raylink access point (FH)
- WaveAccess
  - Makes adapters, access points, bridges

Equipment Manufacturers

- Intermec
  - Makes adapters, access points
  - Was the first to offer a universal access point
    - Enables users to mix radio technologies within the enterprise network
  - Intermec's Wireless PC & ISA cards (DS)
  - Intermec's 2100 Universal Access Point (DS)
  - Its platform dubbed Integrated Network Communications Architcture (INCA) is the only one supporting 400MHz UHF, 900 MHz, 2.4GHz open air, IEEE 802.11 DS, IEEE 802.11 FH
- Nortel Networks
  - Access points

Equipment Manufacturers

- Breezecom
  - Makes adapters, access points, bridges
  - BreezeNET PRO.11 single-port adapter (FH)
  - BreezeNET PRO.11 access point (FH)
- Cabletron
  - RoamAbout PC Card (DS)
  - RoamAbout access point (DS)
- Ericsson
  - Bridges, residential gateways, access points

Equipment Manufacturers

- Dell
- RadioLAN
- MaxTech
- NDC
- No Wires Needed
- Zoom

Where does Xilinx Fit in WLANs?

- Everything!!
  - Enabling broadband local loop in digital modems
    - xDSL, cable, satellite
  - Residential gateways
  - Bridges
    - Enabling different technologies to co-exist
  - Access points
  - Extension points
  - PC cards
  - Enabling the information appliance network
    - Within information appliances
      - Web tablets, screen phones, digital TV/HDTV

Agenda

- Introduction to wireless home networking
- Wireless LAN technology
- Consortiums
- IEEE 802.11
- HiperLAN & HiperLAN2
- Products & solutions available in the industry today
- Xilinx solutions in wireless LAN products
- Summary

Xilinx High Volume Applications Opportunity

Chaos in the HN Marketplace

- Multiple broadband & multiple Home LAN technologies
- Too Many Standards & Too Many Specs

	RF - Wireless	Phoneline	Powerline
Pros	Mobility - UNTETHERED Broad geography support at specific frequencies Can compliment a wired network with bridging	Low cost and fast (10Mbps+) Strong Industry Alliance (HPNA) Dedicated home bandwidth Voice and data share existing lines	Electrical outlets in every room easy connection for non-PC appliances Low cost - will drop with silicon integration High performance (up to 10Mbps)
Cons	Relatively expensive - getting cheaper Distance limits & wall attenuation (150 ft/10 barriers) Security must be addressed Prone to narrowband interference	Phone jacks not near every PC in home Different phone lines (numbers) isolated International deployment issues	Must be robust in hostile environment (noise, stubs, vnet) International deployment issues (Regulatory issues) Security must be addressed Standards need to be addressed
Snapshot Take Away	International Solution, Mobile in North America	Low-cost desktop solution for North America	Ideal for non-PC devices

Chaos in the HN Marketplace

- The three major wireless consumer home networking campaigns are racing in separate directions
  - Wireless LAN/Ethernet, HomeRF & Bluetooth technologies vary in data rate, range, frequency & marketplace aimed for

Technology		Data Rate (Mbits/sec)	Range (meters)	Frequency (GHz)	Technology Aimed For
Wireless LAN/ Wireless Ethernet	802.11	2	100	2.4	Office Enviornments
	802.11b	11	100	2.4	
	802.11a	~40	TBD	5	
Bluetooth	802.15 (Bluetooth)	<1	10	2.4	Consumer, short-range, wireless personal-area technology
	802.15 (high-rate)	20+	TBD	2.4/5	
Home RF	HomeRF	1.6	50	2.4	Home Space
	HomeRF (next gen)	10	50	2.4	

Home Networking Today

- Growing chaos in this emerging technology
  - Solutions are just coming to market
  - Leading players are showing indecisiveness towards different varying technologies
    - Building independent solutions
    - Participation in multiple consortiums
    - Different wireless standards for same frequency band
- Interoperability is a key factor to market success
- Future revisions already in the works
  - HomePNA is already out with v2.0

Implications of this Chaos...

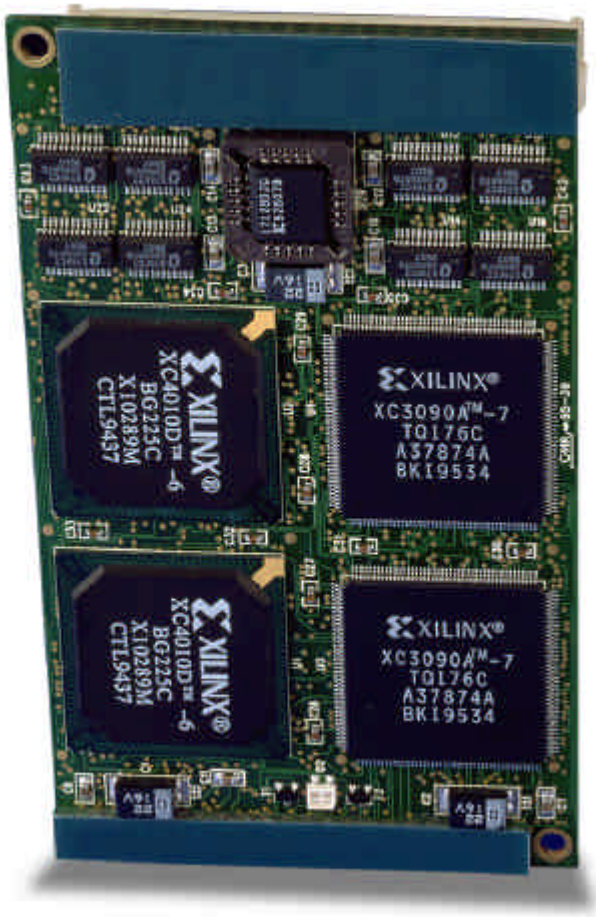
- Brings about an Environment That Guarantees Unanticipated Problems
  - Bugs
  - Incompatibilities
  - The Great Unknown about what is going to be the changes
- Translates to a Steep Learning Curve
  - Virtually mandates a “Ready, Fire, Aim” development model
    - Plan products for the longest life cycles
    - Get a product to market “now”
    - Rapidly integrate refinements and enhancements

Where Does Xilinx Fit In the Electronics Industry

Key components of an electronics system:

- Processor
- Memory
- *Logic*

Xilinx is the Leading Innovator of Complete Programmable Logic Solutions



Strategic Business Model Ensures Focus

- "Fabless" strategy
  - Leading edge IC process technology
  - Wafer capacity at competitive prices
  - Fastest, lowest cost, densest parts
- Independent sales organization (Reps & Distributors)
  - Sales is a variable cost
  - Permits greater reach—over 20,000 Customers
  - Over 10,000 "Feet On The Street"
- Focus on key strengths
  - Product design
  - Marketing
  - Applications & Technical Support

Xilinx Steering Consortiums

Home Phoneline Network CERTIFIED

WLANA The Wireless LAN Association

HiperLAN2 Global Forum

LONMARK INTEROPERABILITY ASSOCIATION

Xilinx Product Portfolio

Advanced Products Group

High Performance
High Density

General Products Division

High Volume
Low Cost

CPLD Division

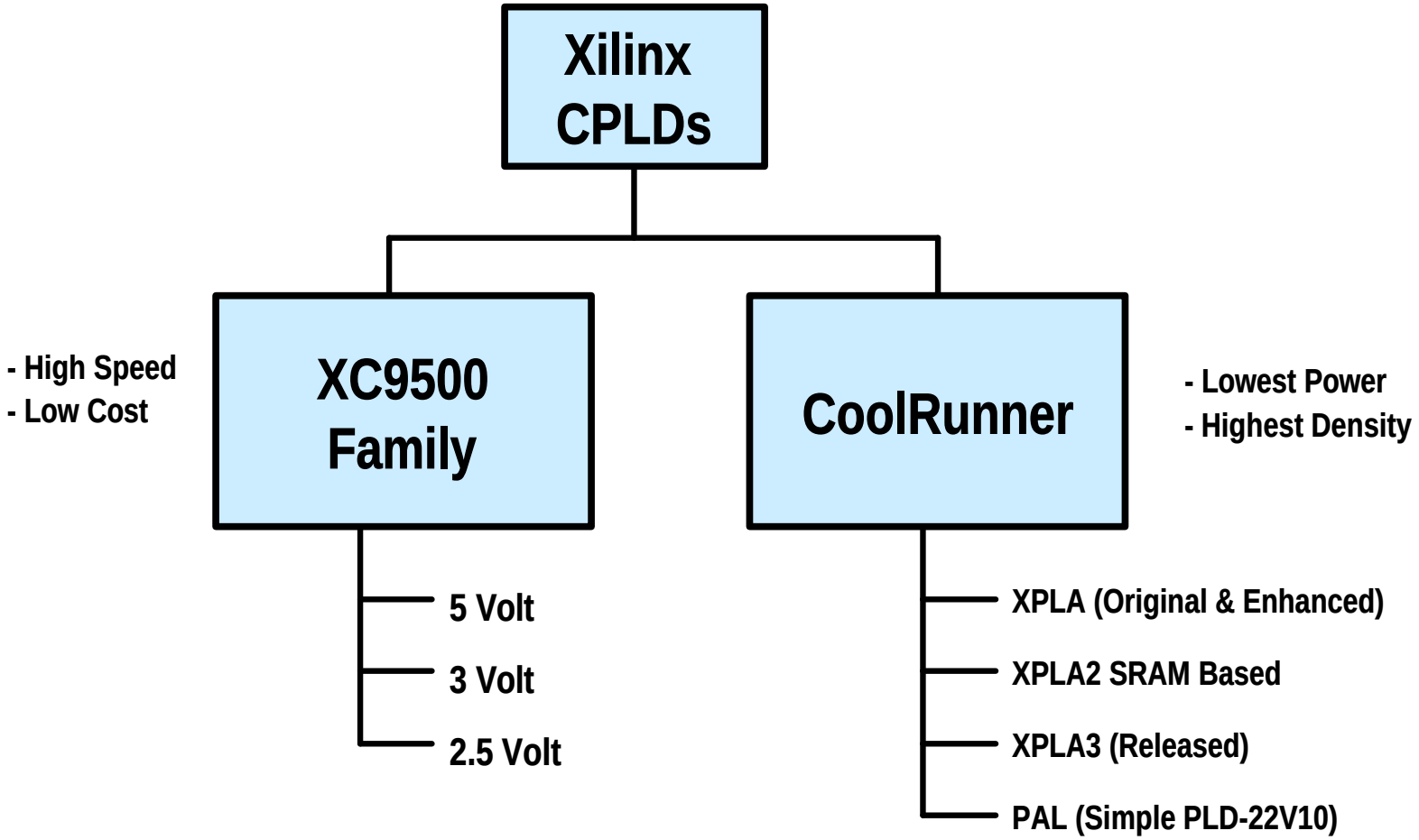
Low Power
Low Cost

Software Solutions

Xilinx - Leader in Core Solutions

	1998	1999	2000	2002	2004
Base Level Functions	- 82xx, UARTs, DMA - 66MHz DRAM, SDRAM I/F - Memory blocks - 29xx - Proprietary RISC Processors	- 8051 - IEEE 1284 - 200MHz SDRAM I/F - SGRAM, ZBTRAM I/F - Multi-channel DMA	- JAVA - Adv 32-bit RISC Processors - 64-bit RISC - DDR/QDR RAM - 622 Mbps LVDS		- 128-bit processors - Reconfigurable processors
Communication & Networking	- Cell assem/delin - CRC - T1 Framer - HDLC - Reed-Solomon - Viterbi - UTOPIA	- 10/100 Ethernet - ATM/IP Over SONET - Cell scram/descram - SONET OC3/12 - ADPCM - IMA	- Network processors - 1Gb Ethernet - SONET OC48/192 - CELP - VoIP - ADSL, HDSL, xDSL - UMTS, wCDMA		- Software Radio - Modems - Neural networking - Emerging Telecom and Networking Standards
DSP Functions	- Basic Math - Correlators - Filters: FIR, Comb - Multipliers - FFT, DFT - Sin/Cos	- DCT - Adaptive filters - Cordic - DES - DES - Divider - NCO - Satellite decoders	- MP3 - QAM - JPEG - Speech Recognition - DSP Processor I/Fs - Wavelet		- MPEG - DSP Functions > 200 MSPS - Programmable DSP Engines
Standard Bus Interfaces	- CAN - ISA PnP - I2C - PCI 32-bit - PCMCIA	- CardBus - FireWire - PCI 64-bit/66MHz - Compact PCI Hot-Swap - PC104 - VME	- AGP - PCI-X 133MHz		- InfiniBand - Emerging High-Speed Standard Interfaces

Xilinx CPLD Families



CoolRunner Technology

- Full density range 32 to 960 macrocells
- World's only TotalCMOS CPLD
  - Bipolar style sense amps eliminated
  - Virtually no static power dissipation
- Advanced PLA Architecture
  - Product term sharing (no redundant logic)
  - No wasted product terms
- 3.3v and 5.0v devices
- ISP/JTAG compatible & full software support

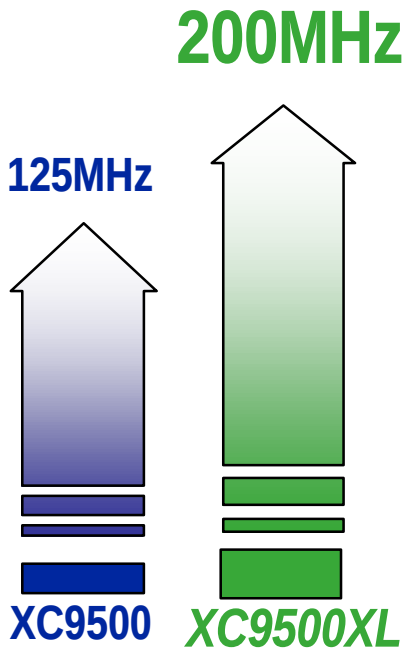
The CoolRunner Advantage

- Industry's lowest power CPLDs
  - Standby current < 100uA
  - High speed TPD = 6 ns
  - Revolutionary XPLA architecture
    - Exceptional routability & pin-locking
    - Fast, predictable timing
  - Small form factor packaging
    - New 0.5mm 56-pin MicroBGA

- No Speed / Power tradeoffs in scaling
  - Can build very large / very fast devices
  - 960 macrocell device @ 7.5 nsec t_{PD}

XC9500XL Key Features

- High performance
  - t_{PD} = 5ns, f_{SYS} = 178MHz
- 36 to 288 macrocell densities
- Lowest price, best value CPLD
- Highest programming reliability
- Most complete IEEE 1149.1 JTAG
- Space-efficient packaging, including chip scale pkg.

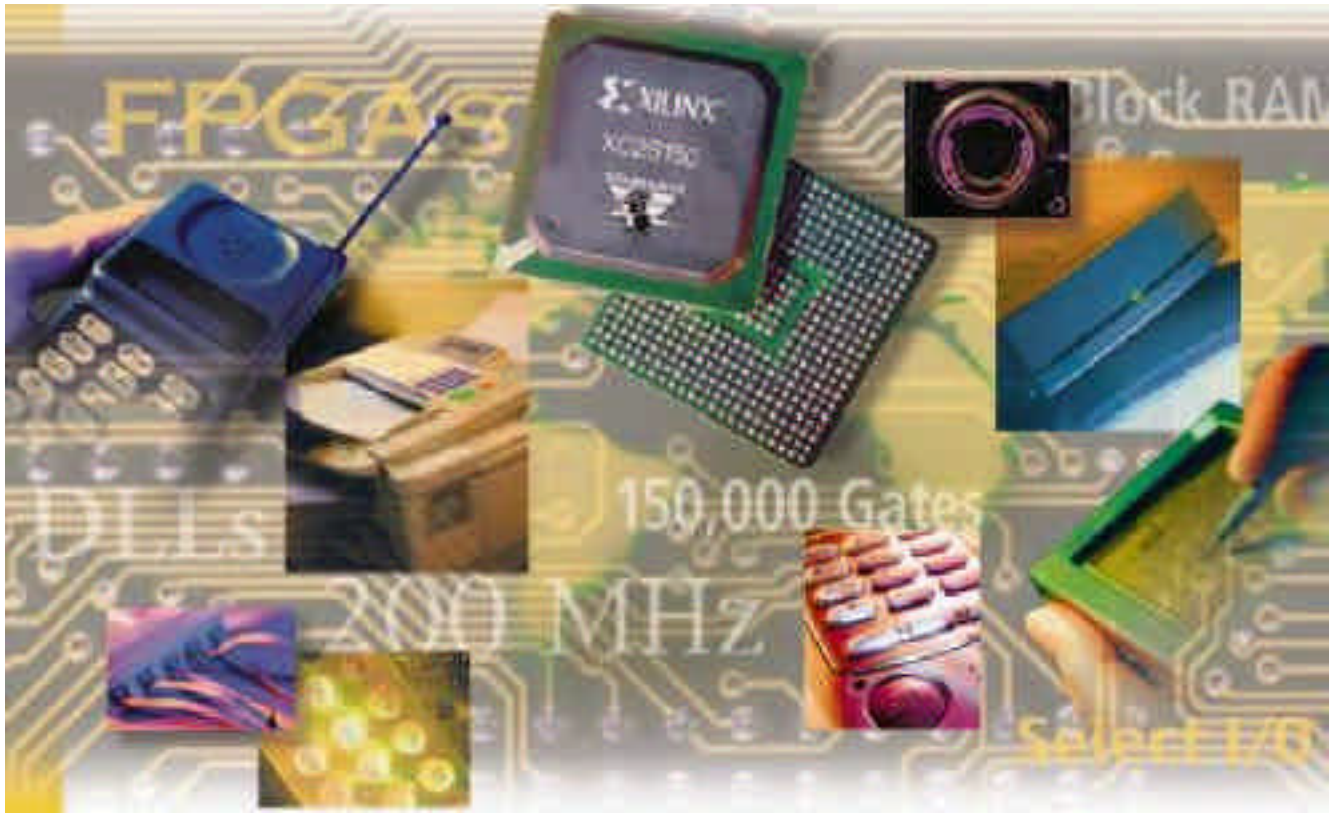


Lowest Price
Per Macrocell

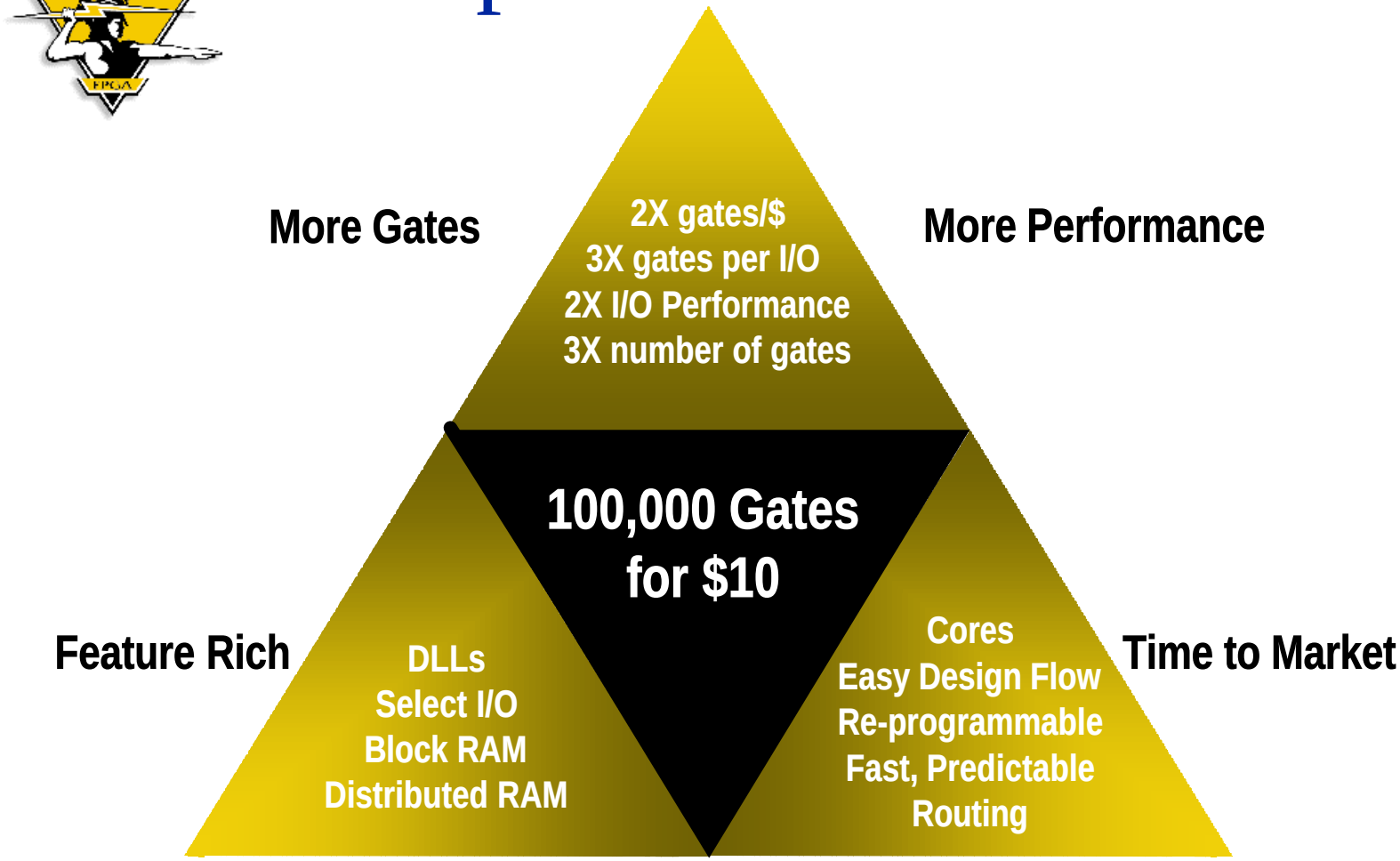
XC9500XL/XV System Features

- I/O Flexibility
  - XL:5v tolerant; direct interface to 3.3V & 2.5V
  - XV:5v tolerant; direct interface to 3.3V, 2.5V & 1.8V
- Input hysteresis on all pins
- User programmable grounds
- Bus hold circuitry for simple bus interface
- Easy ATE integration for ISP & JTAG
  - Fast, concurrent programming times

Introducing the Spartan-II FPGA

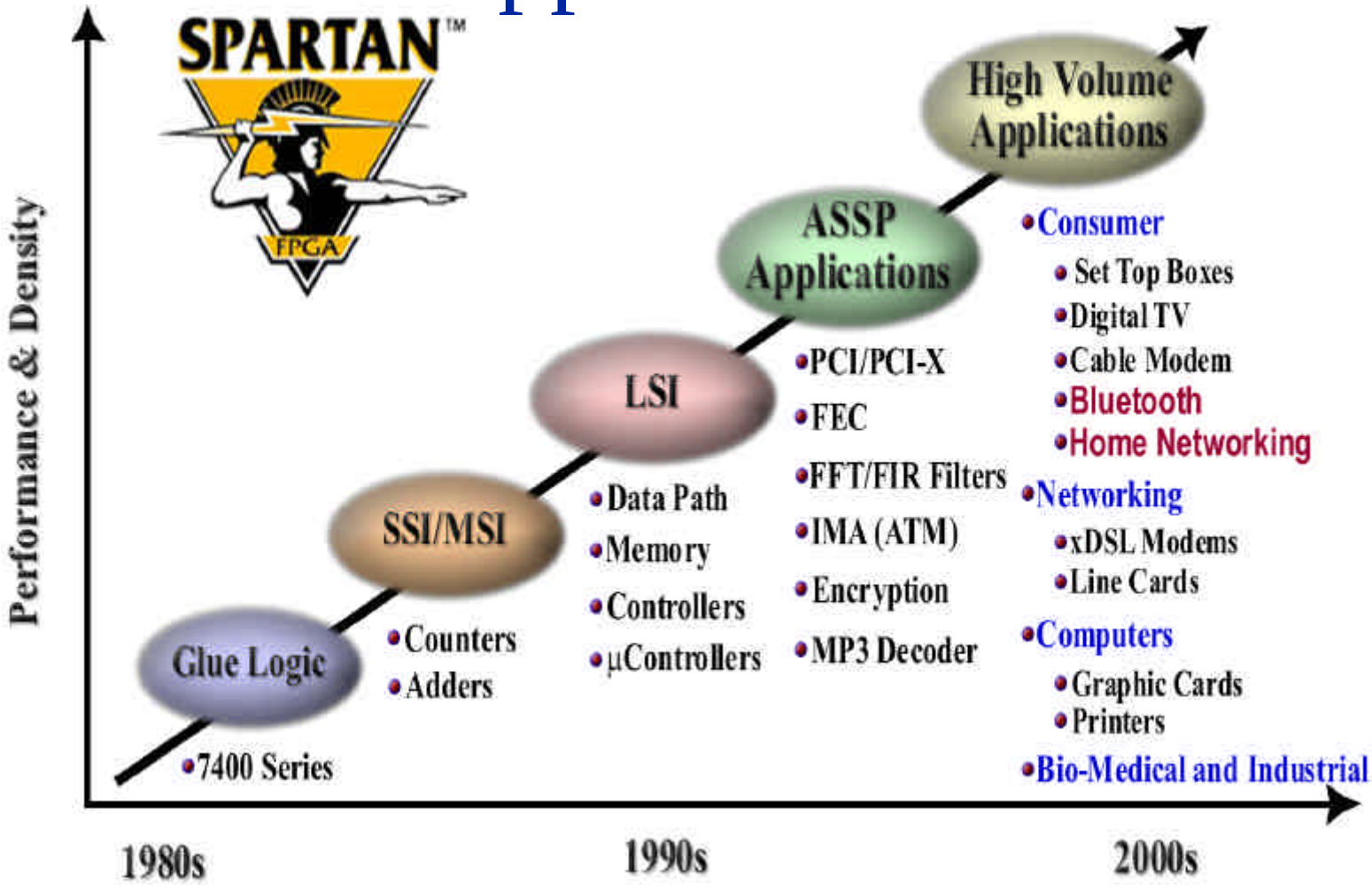


Spartan-II: Extending the Spartan Series



Programmable ASIC/ASSP Replacement!

FPGA Application Trends



Programmable ASIC/ASSP Replacement!

Spartan-II - Architecture Overview

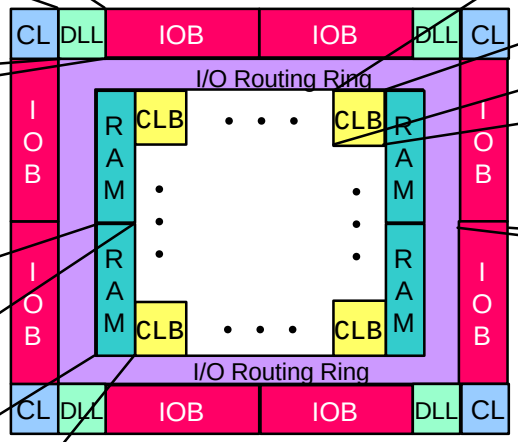
Delay Locked Loop (DLL)

Clock Management:

Multiply clock
Divide clock
De-skew clock

Configurable Logic Blocks (CLB)

Configurable Logic Block Array and Distributed RAM



Select I/O™ Technology

Chip to Backplane
PCI 33MHz 3.3V
PCI 33MHz 5.0V
PCI 66MHz 3.3V
GTL, GTL+, AGP
Chip to Memory
HSTL-I, HSTL-III
HSTL-IV
SSTL3-I, SSTL3-II
SSTL2-I, SSTL2-II
CTT
Chip to Chip
LVTTL, LVCMOS

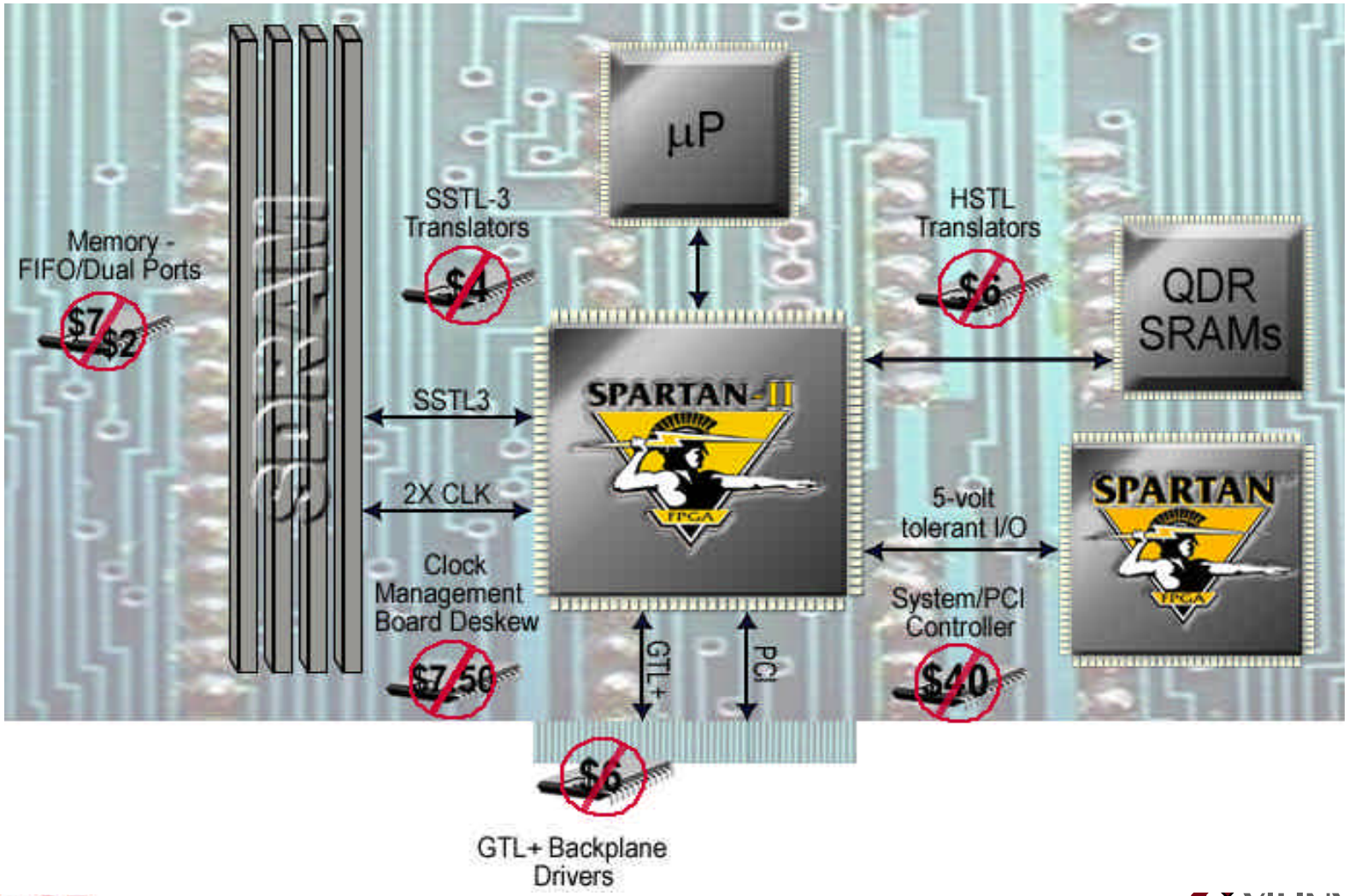
Block Memory

True Dual-Port™ 4K bit RAM

4Kx1
2Kx2
1Kx4
512x8
256x16

"The Spartan-II family, in our opinion, may be the closest that any FPGA has come to being at a low-enough price to compete against an ASIC"
--Dan Niles, Industry Analyst

Spartan-II - System Integration



Spartan-II Core Support

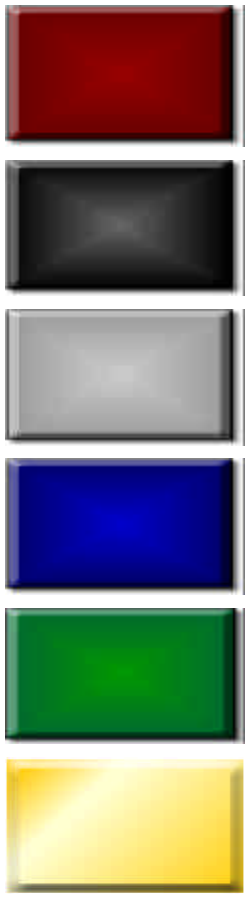
- On-chip memory & storage
  - Distributed, BlockRAM, FIFOs
- Bus products
  - PCI (64- & 32-bit, 33/66MHz), Arbiter, CAN bus interface
- DSP Functions (FIR filter)
- Error correction
  - Reed-Solomon, Viterbi
- Encryption (DES & triple DES)
- Microprocessor
  - ARC 32-bit configurable RISC, 8-bit 8051 microcontroller
- Memory controllers (10+)
  - SDRAM, QDR SRAM
- Communications
  - ATM (IMA, UTOPIA), Fast Ethernet (MAC)
- Telecom
  - CDMA matched filter, HDLC, DVB satellite, ADPCM speech codec
- Video & image processing
  - JPEG codec, DCT/IDCT, color space converter
- UARTs

Spartan-II End Applications

- Consumer
  - Set Top Boxes/Digital VCRs
  - DTV/HDTV
  - Digital Modems
    - xDSL, Cable, Satellite
  - Home Networking products
  - Bluetooth appliances
  - LCD/Flat-Panel Displays
- Networking
  - Telecom linecards
  - DSLAMs
  - LAN Hubs/Switches
  - SOHO Routers
  - Cellular base stations
- Computer/Storage
  - Printer/Scanner
  - Multi-function office equipment
  - Storage devices
  - Home servers
  - Audio/Video add-in cards
- Industrial/Medical
  - Medical Imaging
  - Industrial automation/control
  - Data acquisition
  - Video capture/editing
  - Automated test equipment
  - Automotive Info-tainment systems

System Block Diagrams for Wireless LAN Solutions

Block Diagram Template / Index



Xilinx Solution

Or

Non-Xilinx Components

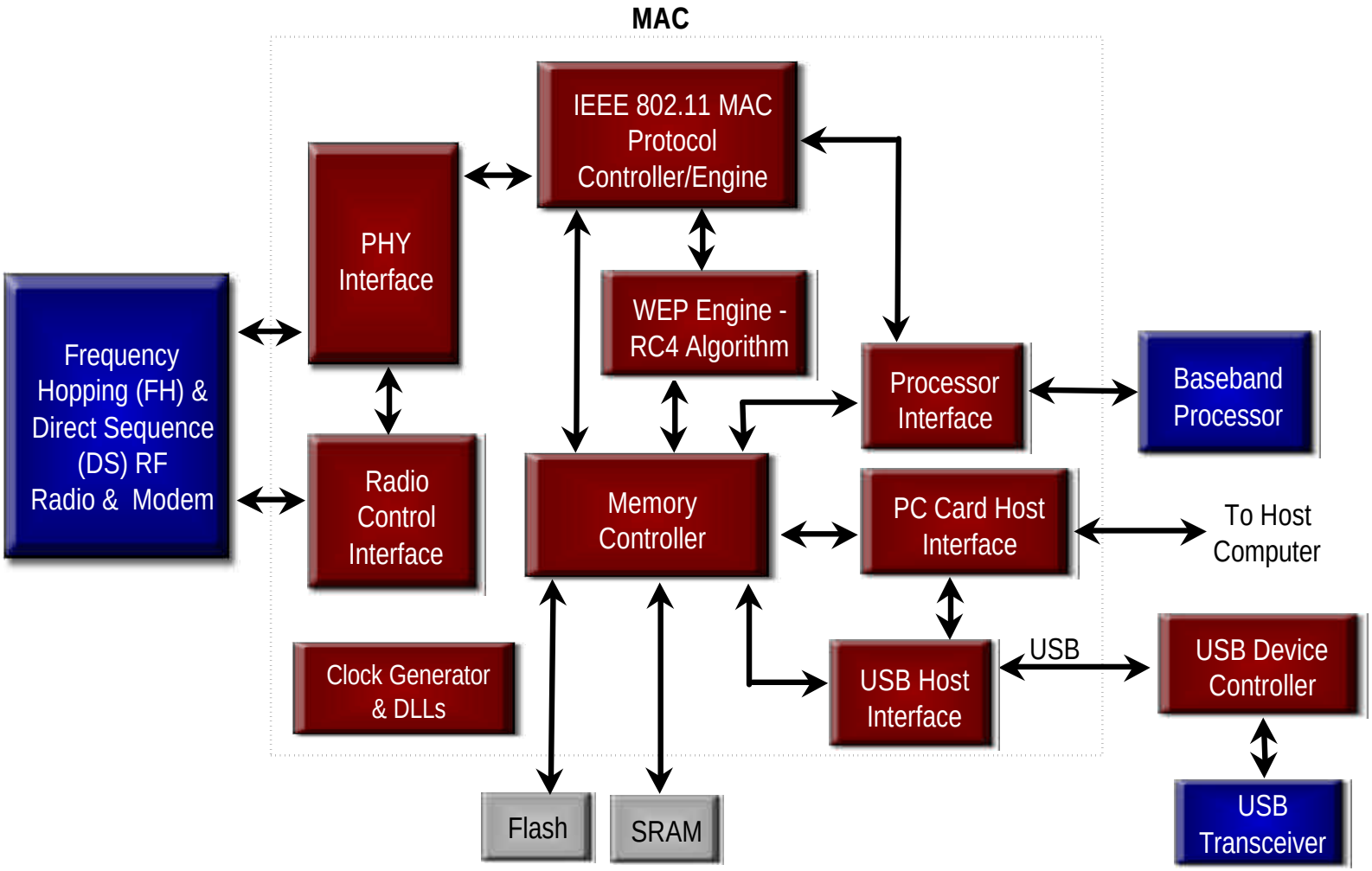
Memory

Mixed Signal / RF

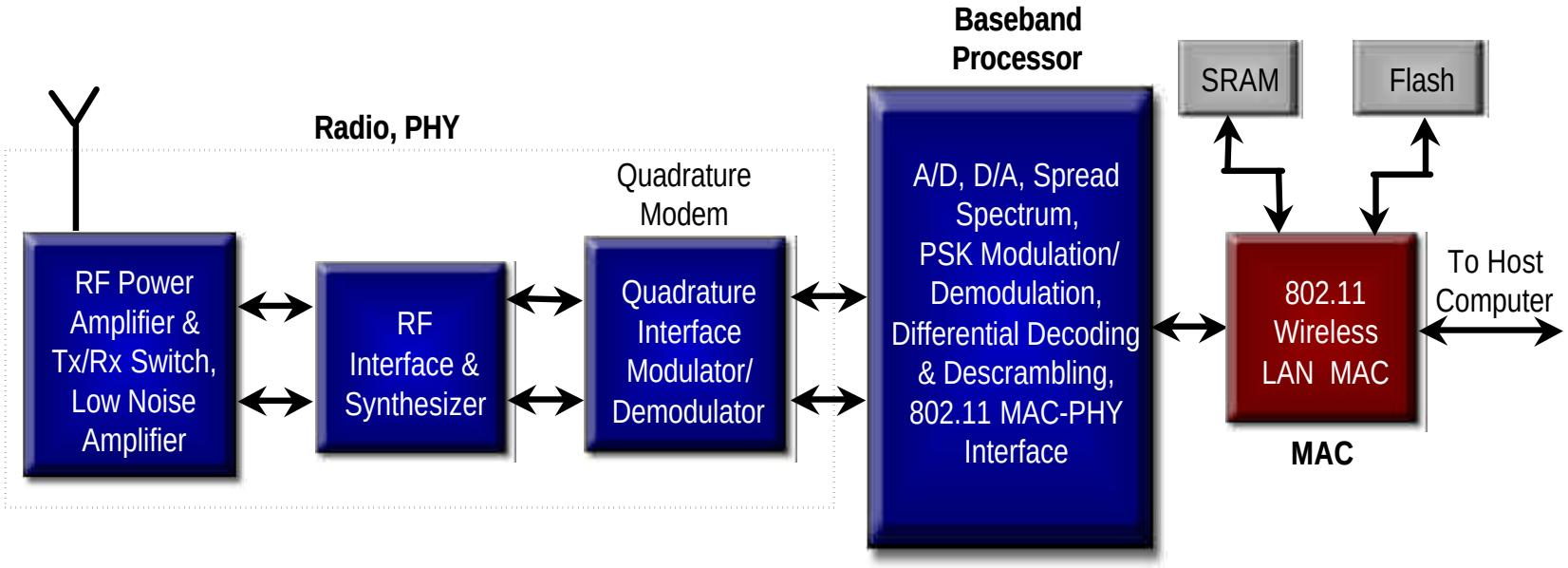
CPU

Embedded Chip

IEEE 802.11 MAC

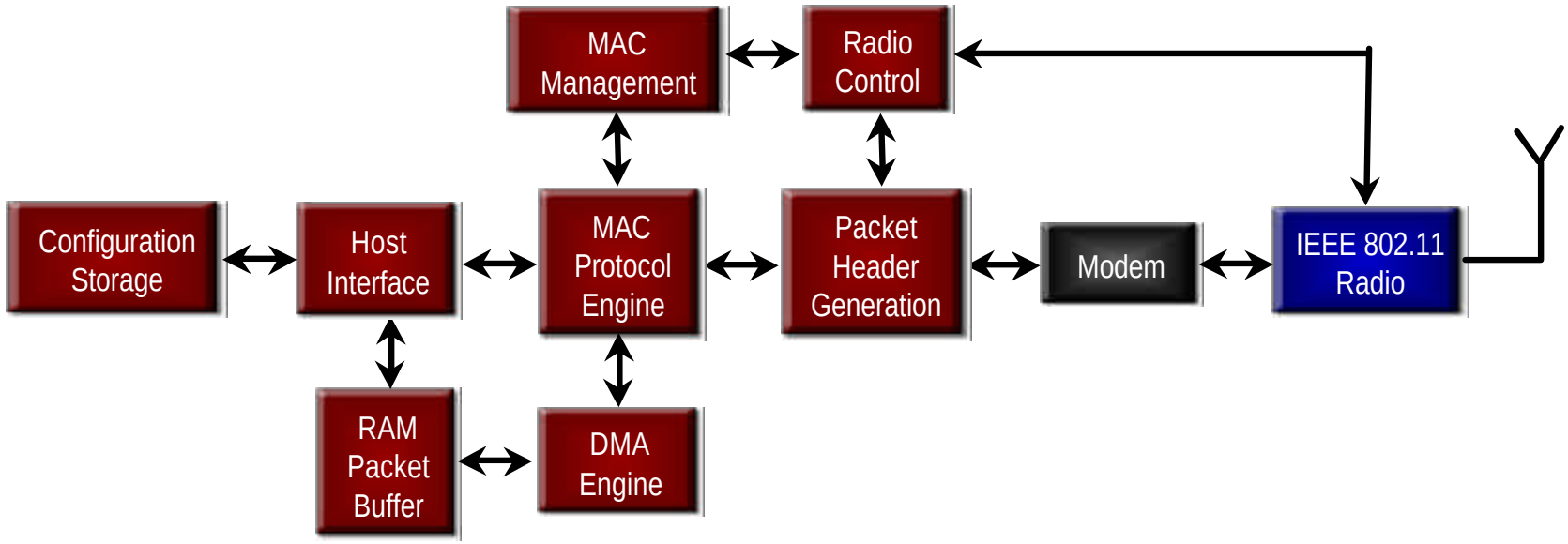


Wireless LAN PC Card Block Diagram

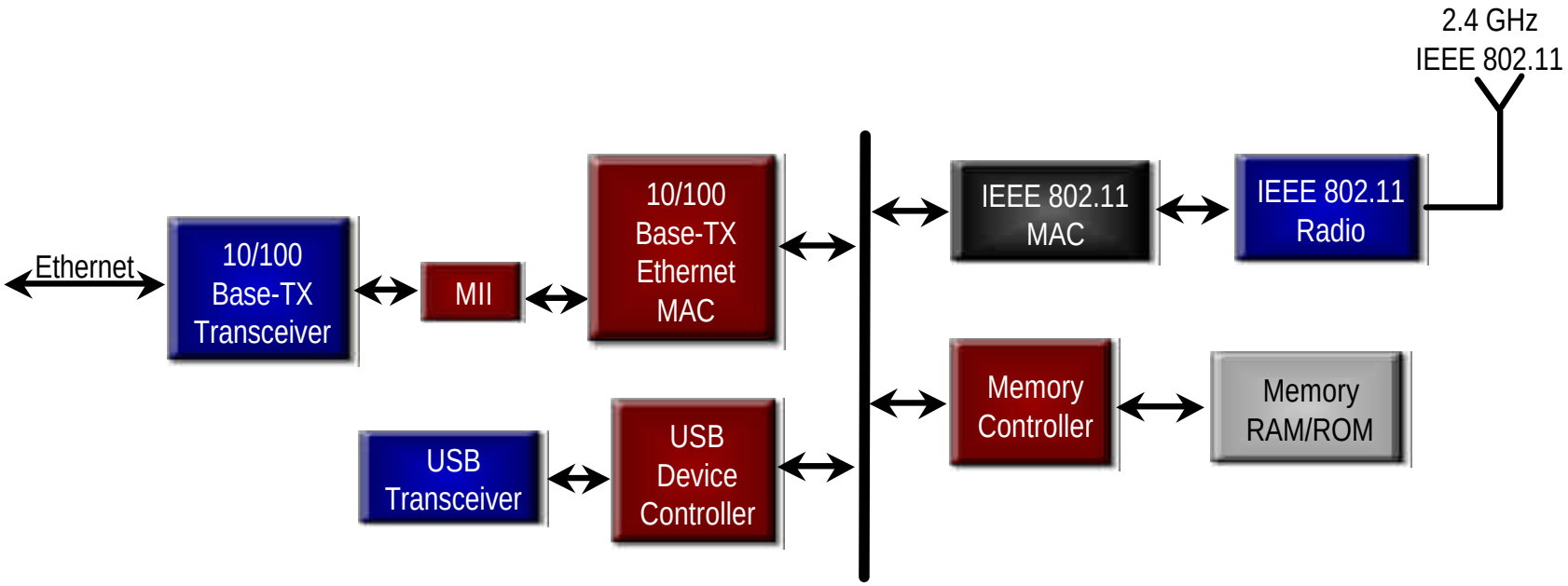


IEEE 802.11 2.4GHz Wireless LAN PC Card Block Diagram Radio, Baseband Processor & MAC

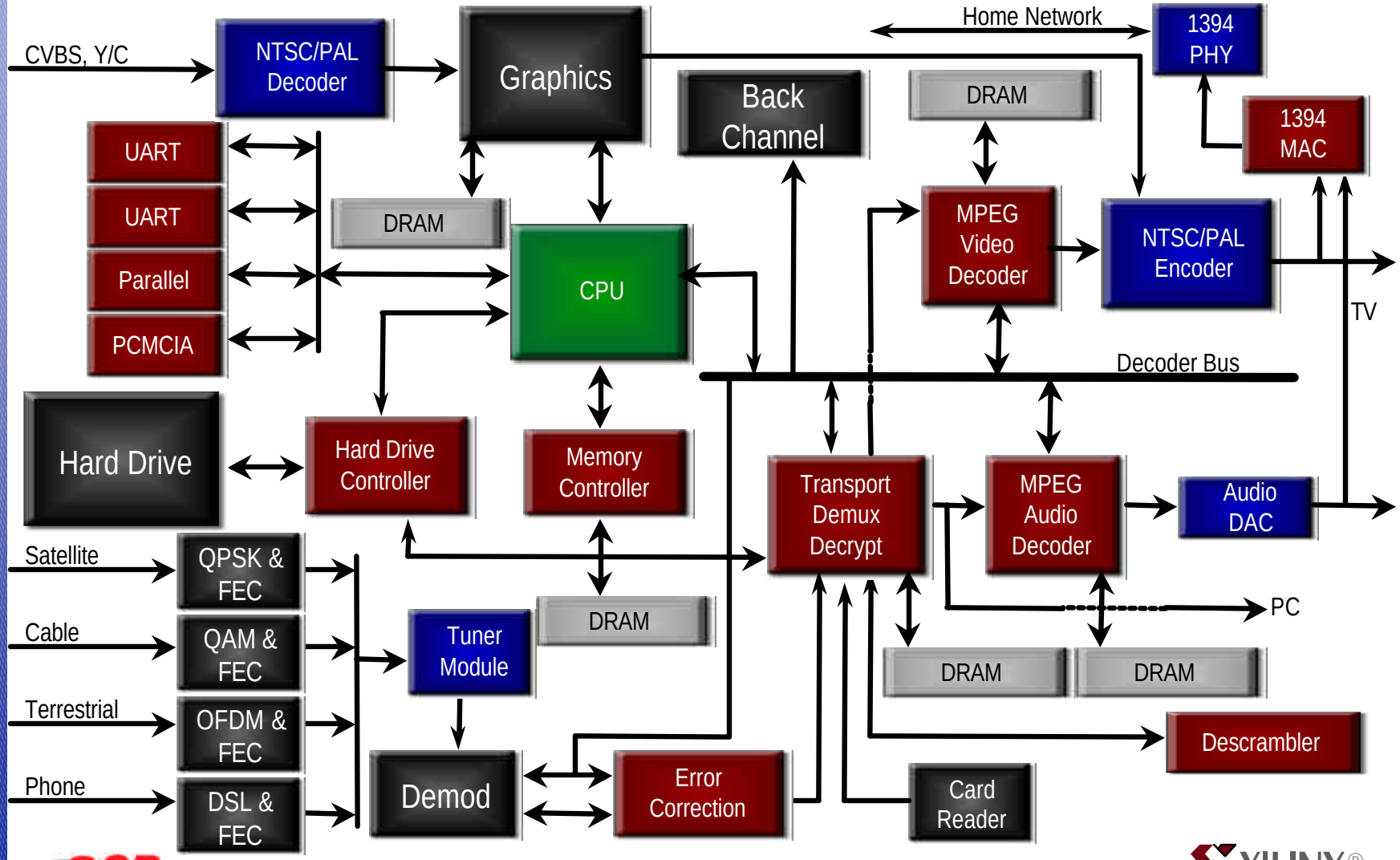
Wireless LAN Card



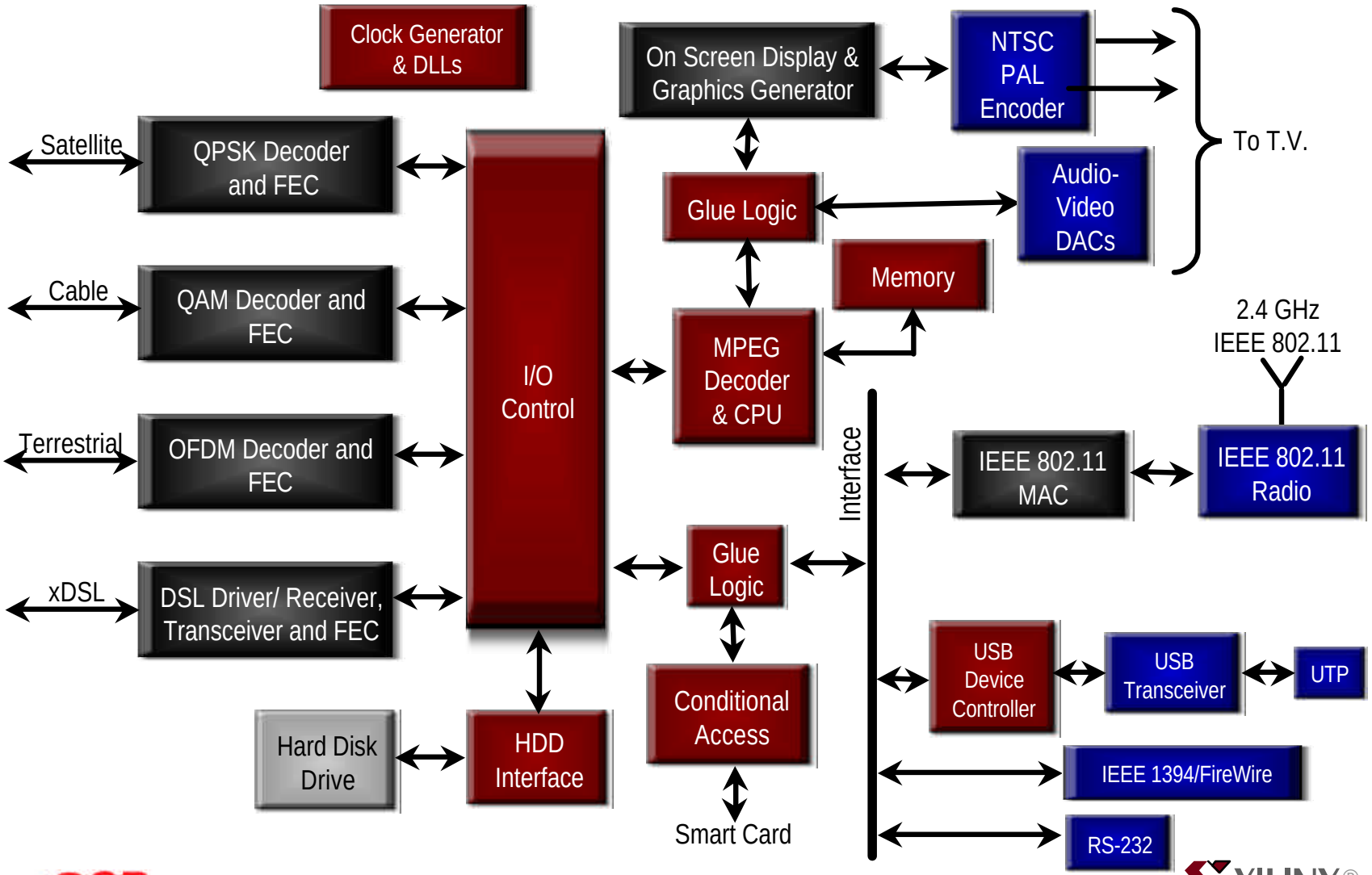
IEEE 802.11 2.4GHz Wireless LAN Access Point



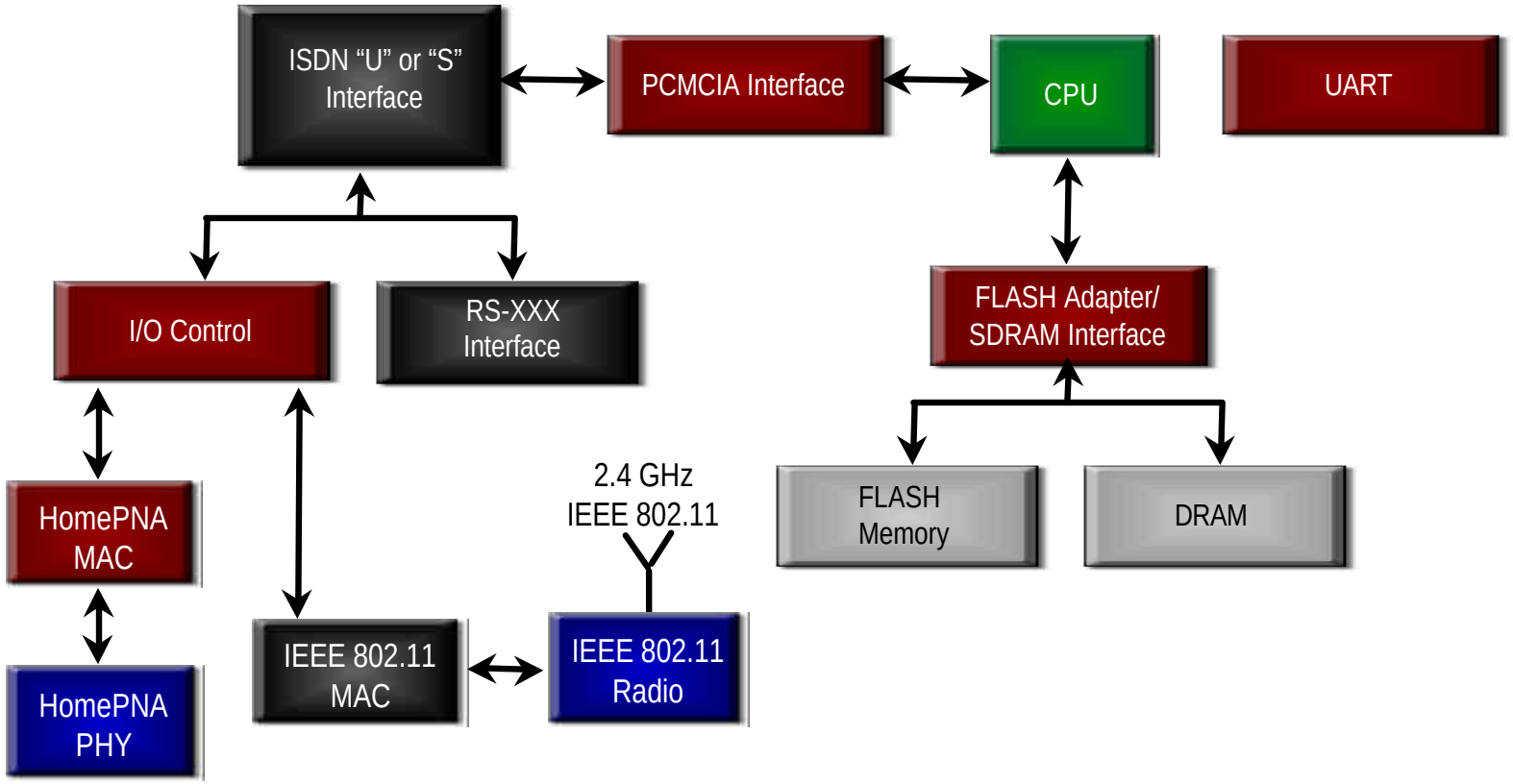
“Super” Set Top Box



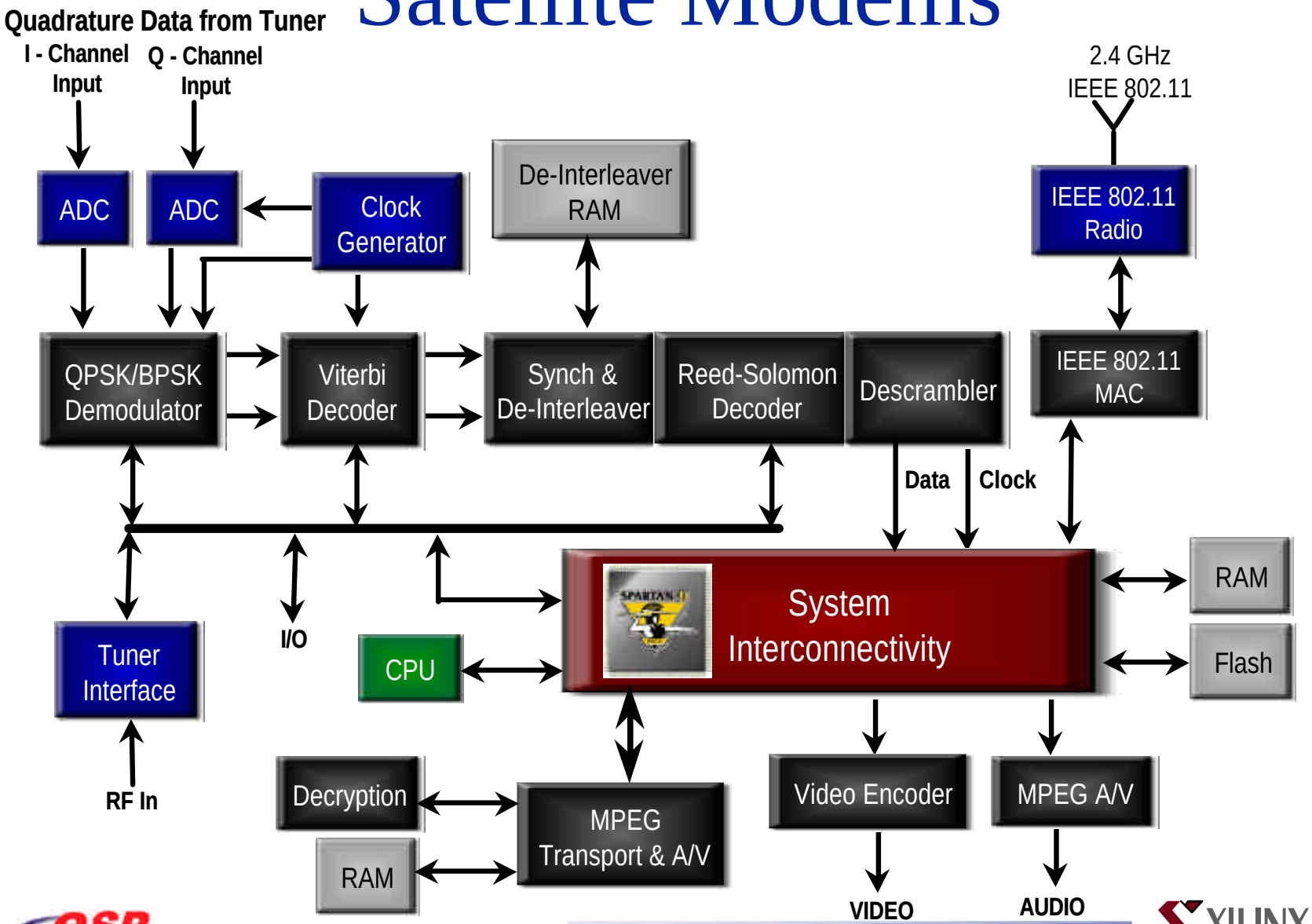
WLAN Residential Gateway



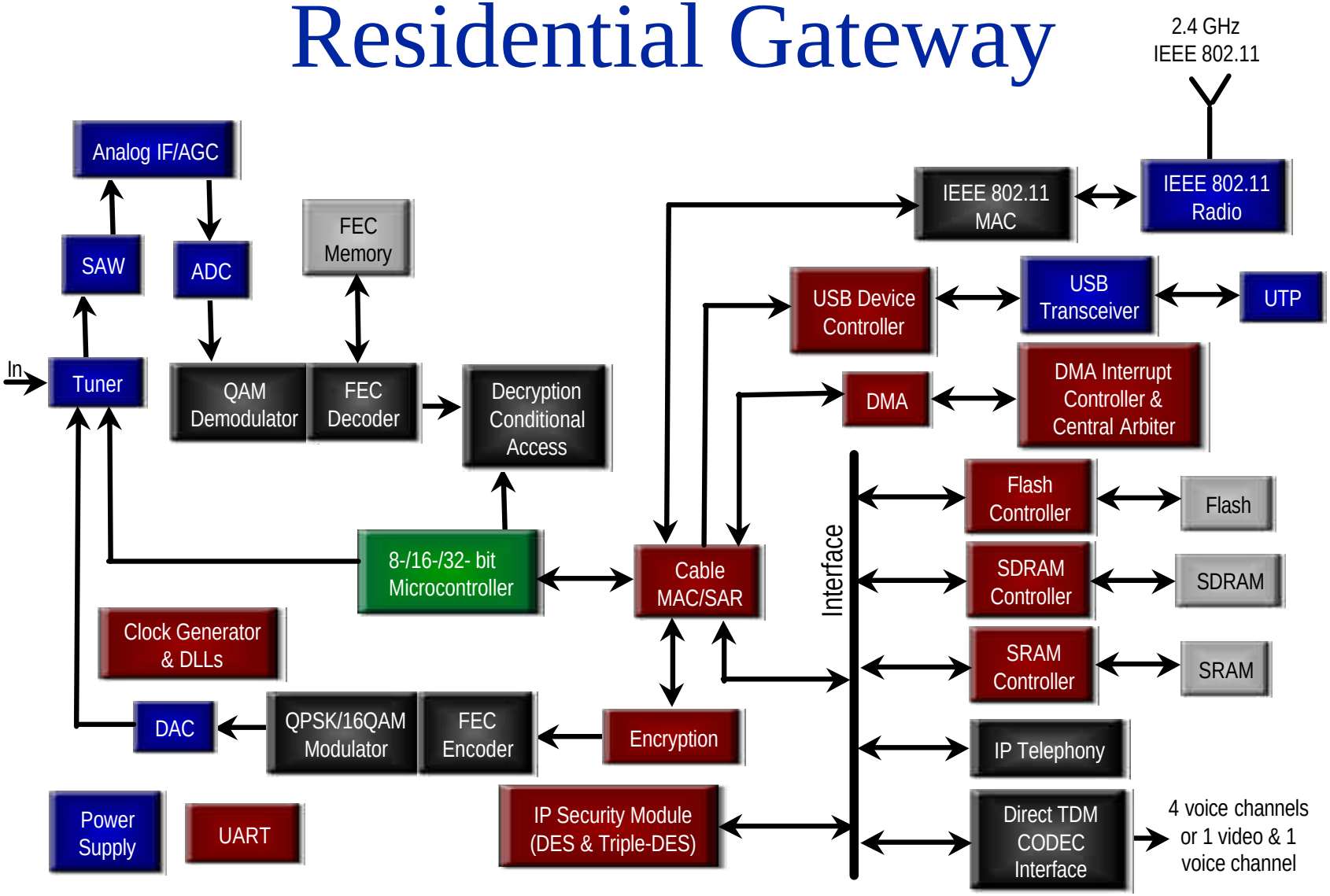
ISDN Modems-Wireless LAN Residential Gateway



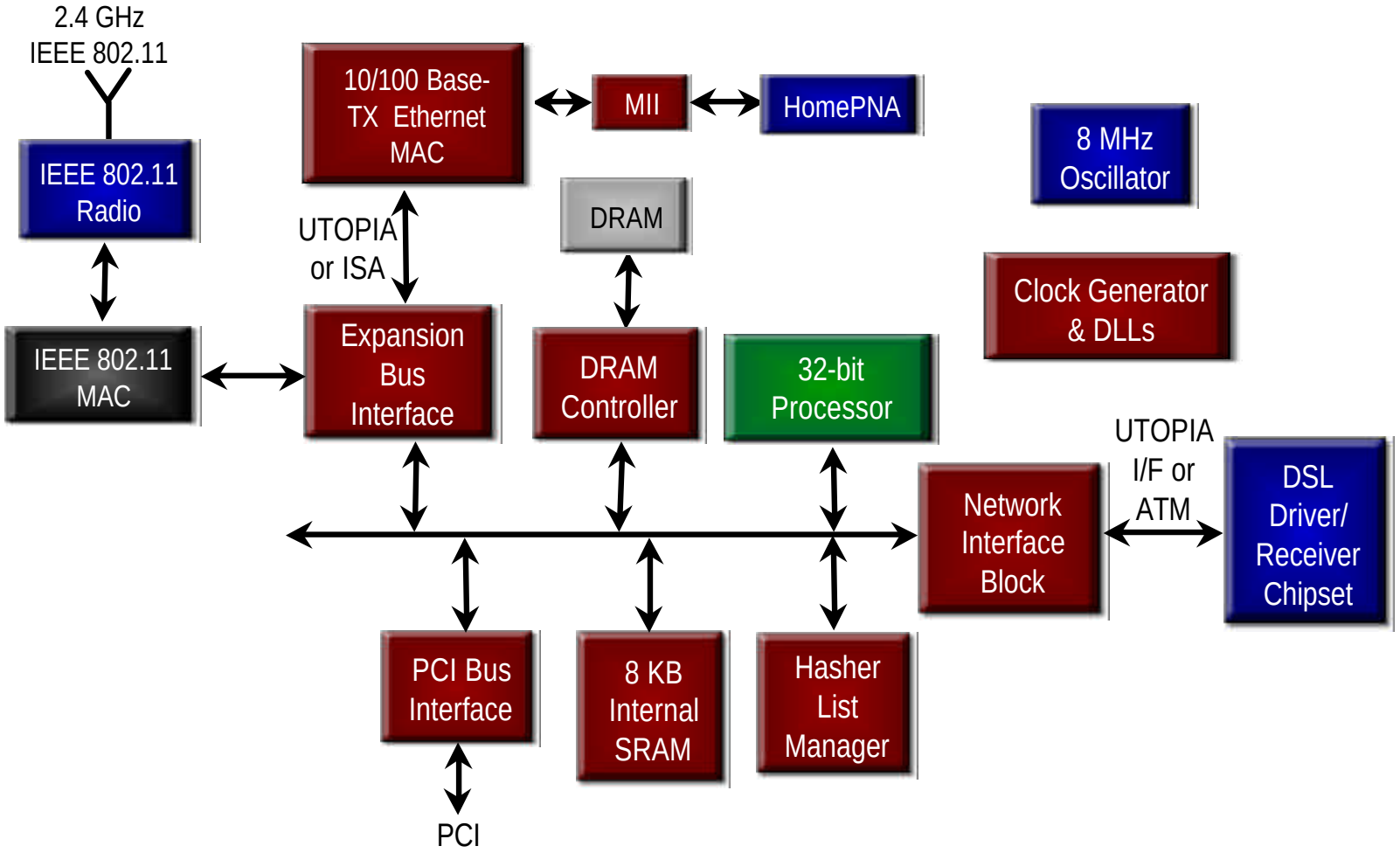
Satellite Modems



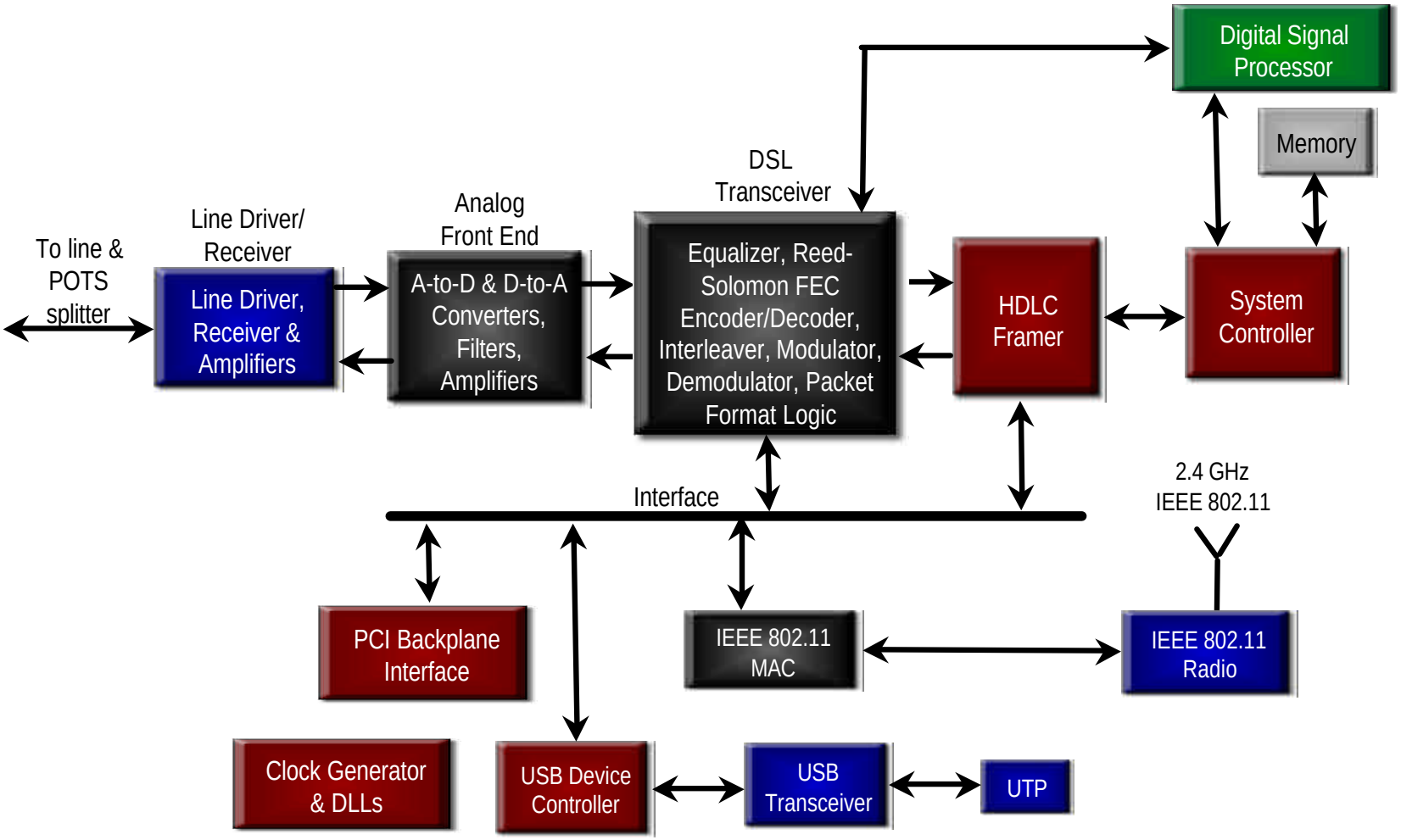
Wireless LAN - Cable Modem Residential Gateway



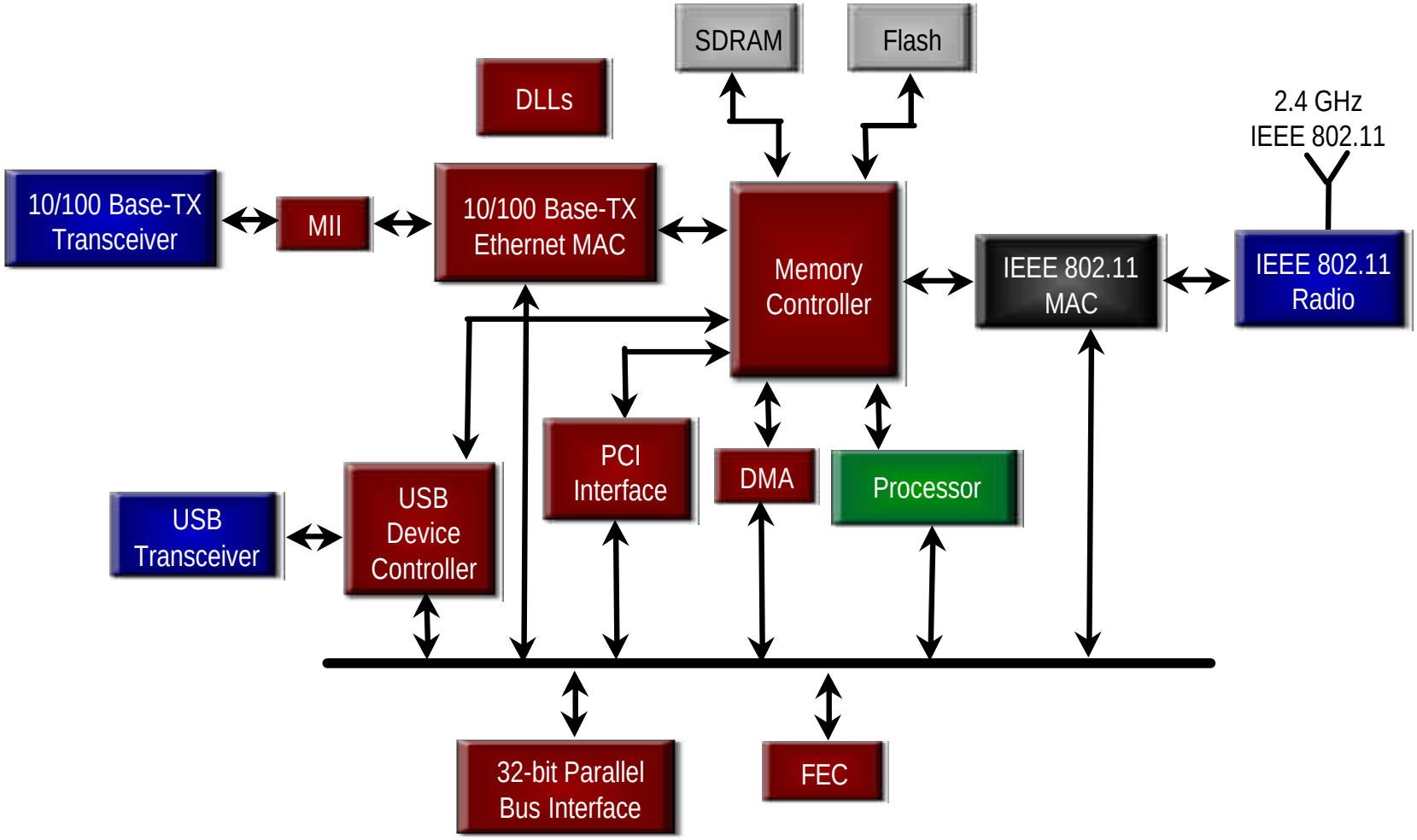
DSL Modem - Wireless LAN Home Gateway



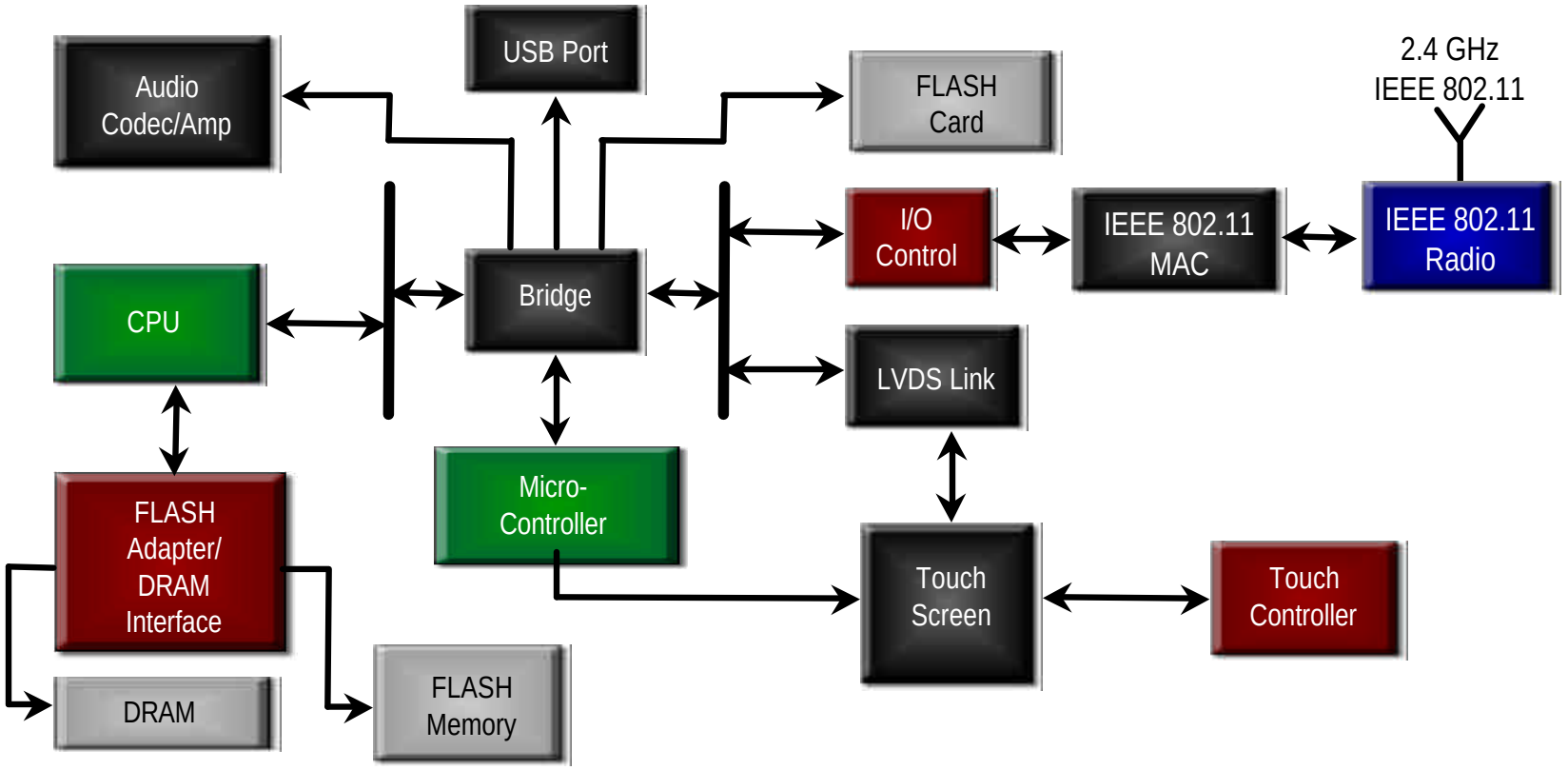
DSL CPE (Customer Premise Equipment)



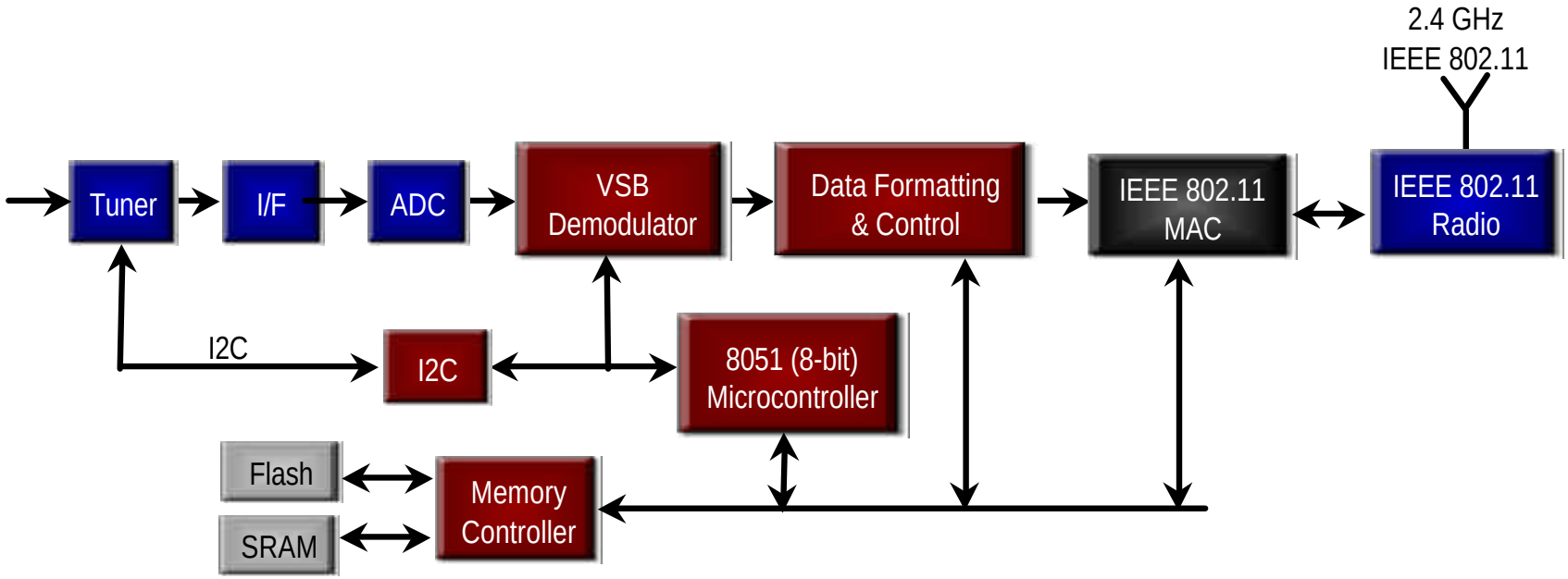
Wireless LAN to Ethernet Bridge
(IEEE 802.11 to IEEE 802.3)



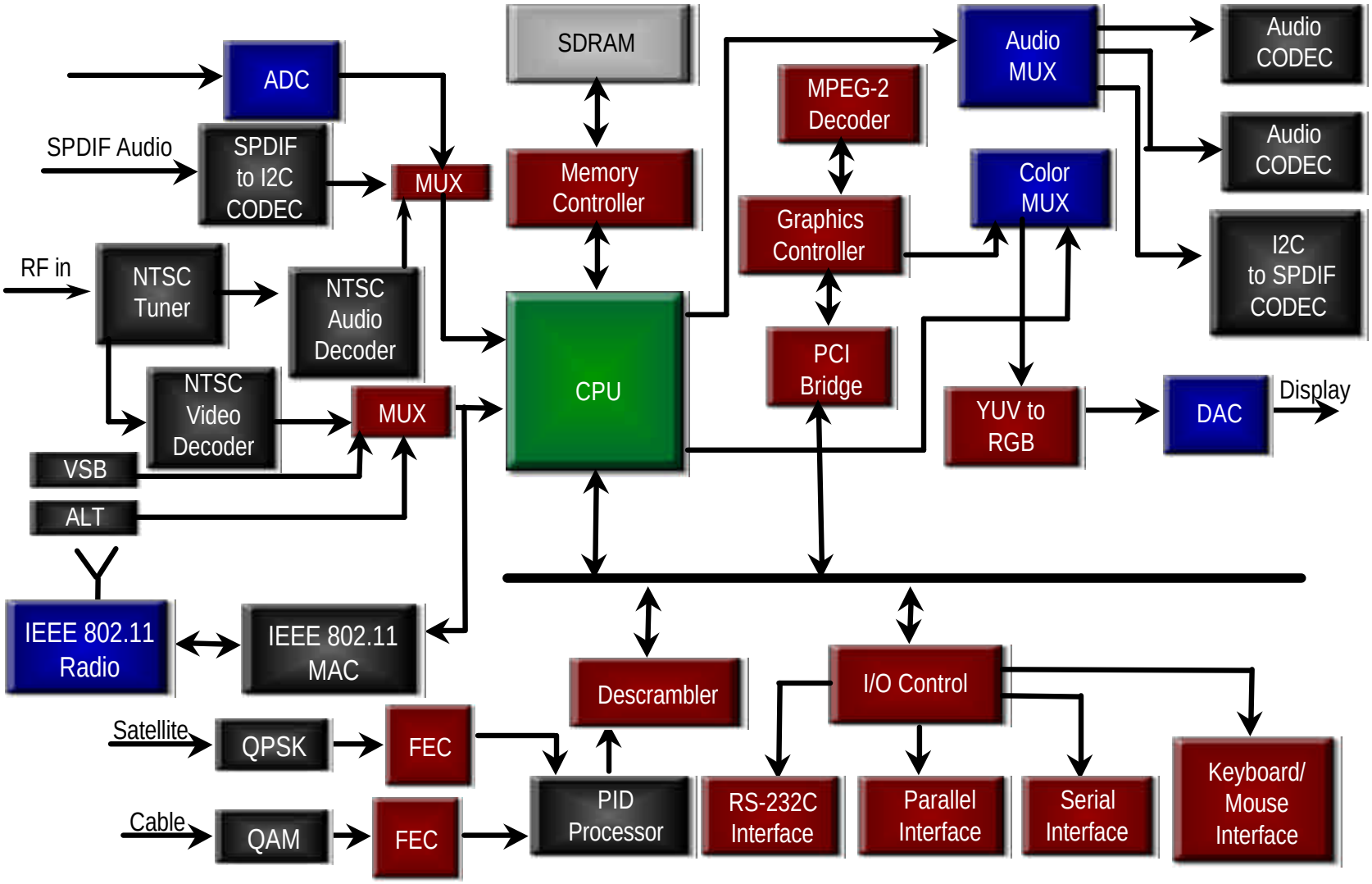
Web Pad / Fridge Pad



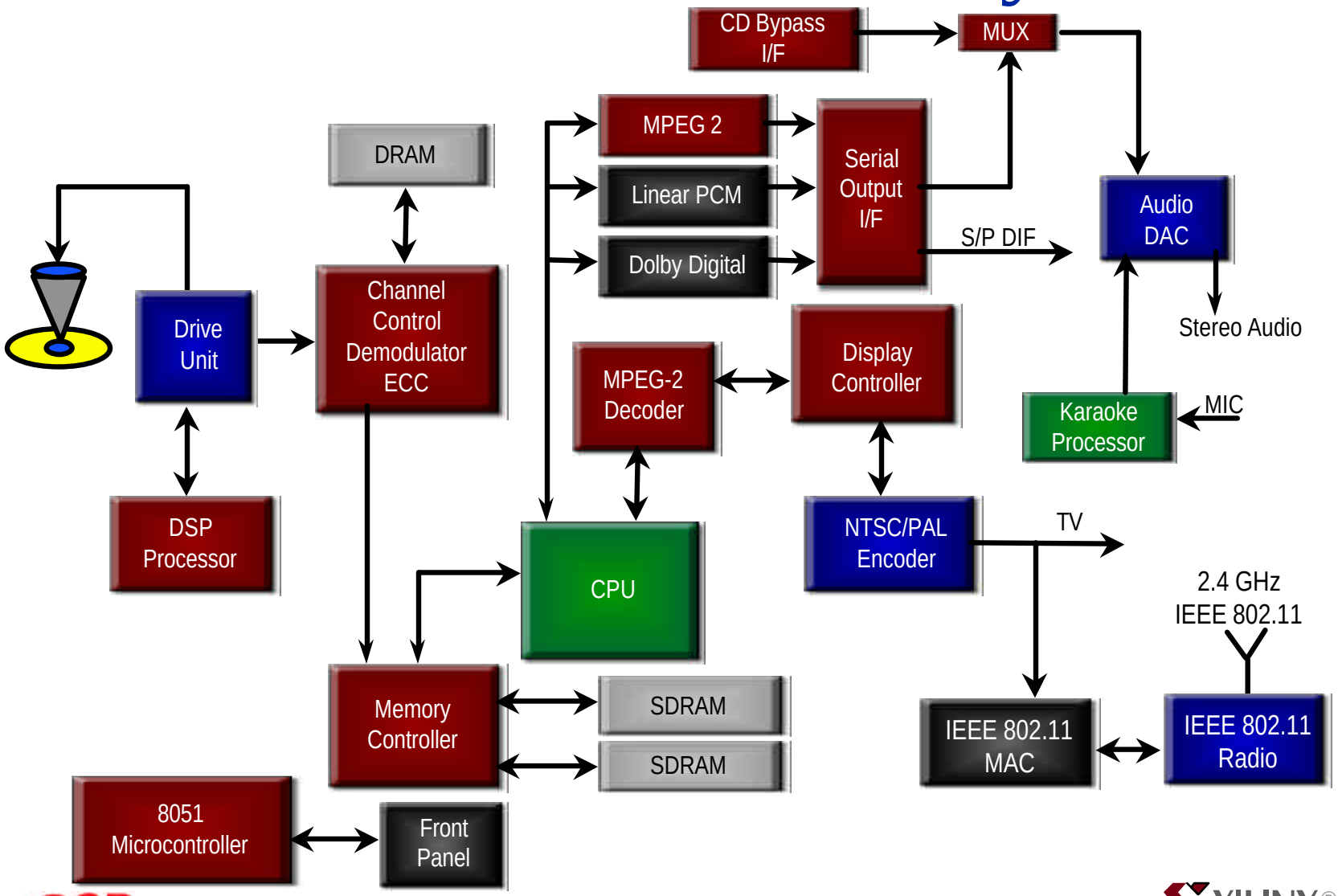
Digital TV


2.4 GHz
IEEE 802.11
Tuner
I/F
ADC
VSB Demodulator
Data Formatting & Control
IEEE 802.11 MAC
IEEE 802.11 Radio
I2C
I2C
8051 (8-bit) Microcontroller
Flash
SRAM
Memory Controller

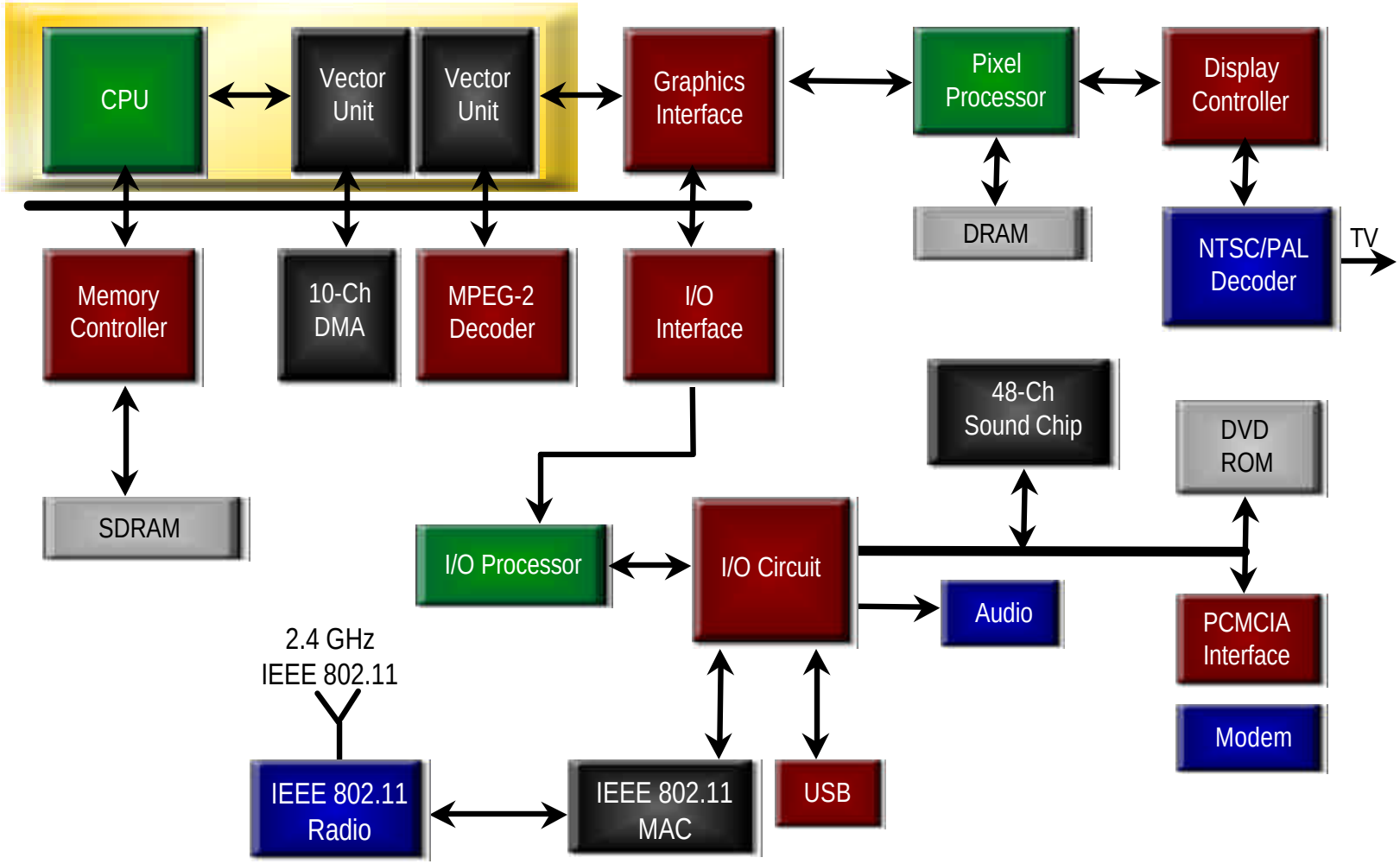
Digital TV


SDRAM
ADC
SPDIF Audio
SPDIF to I2C CODEC
MUX
Memory Controller
MPEG-2 Decoder
Audio MUX
Audio CODEC
Audio CODEC
Color MUX
Graphics Controller
I2C to SPDIF CODEC
RF in
NTSC Tuner
NTSC Audio Decoder
NTSC Video Decoder
MUX
CPU
PCI Bridge
YUV to RGB
DAC
Display
VSB
ALT
IEEE 802.11 Radio
IEEE 802.11 MAC
Descrambler
I/O Control
Satellite
QPSK
FEC
Cable
QAM
FEC
PID Processor
RS-232C Interface
Parallel Interface
Serial Interface
Keyboard/ Mouse Interface

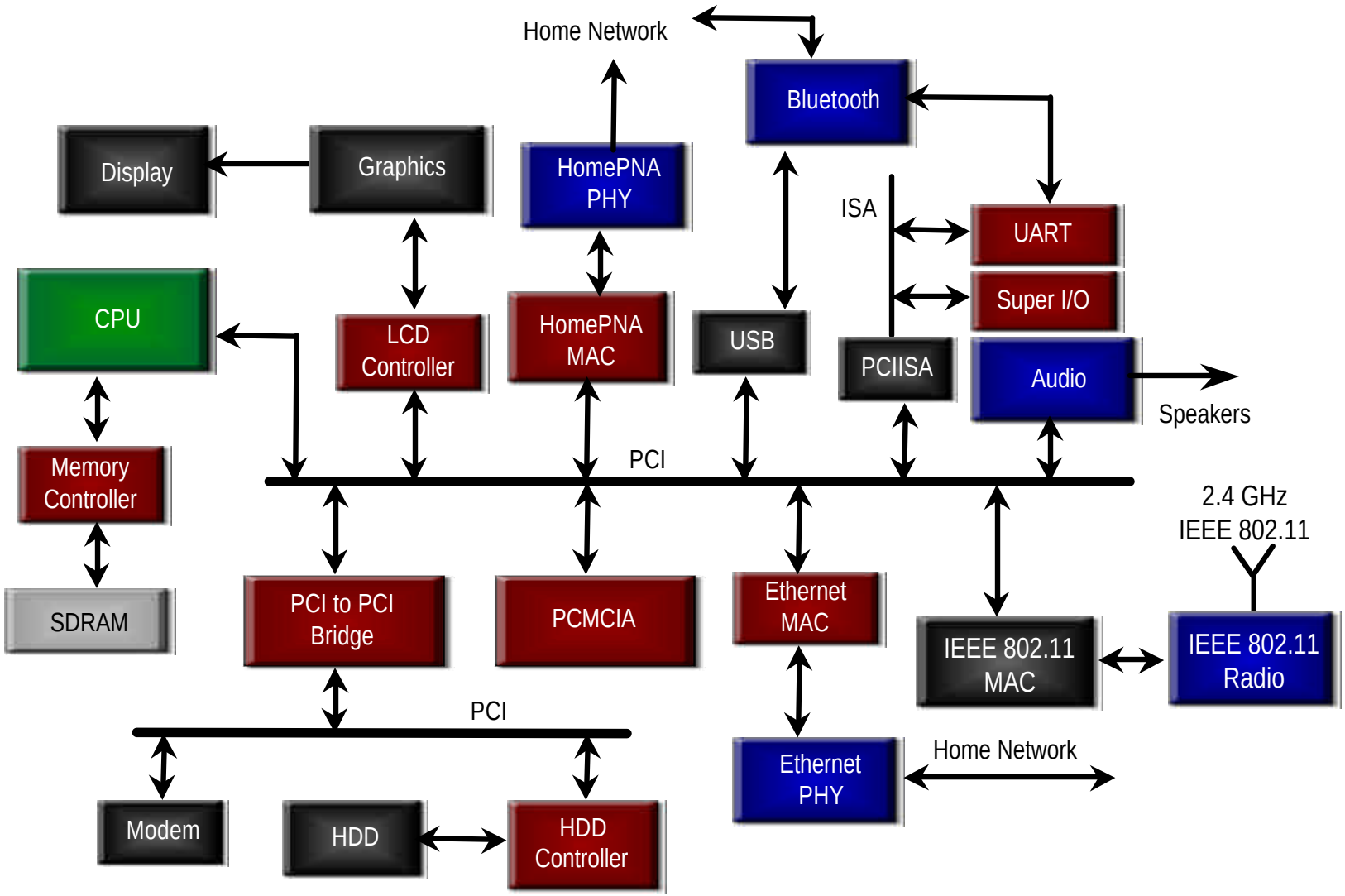
Interactive DVD Player



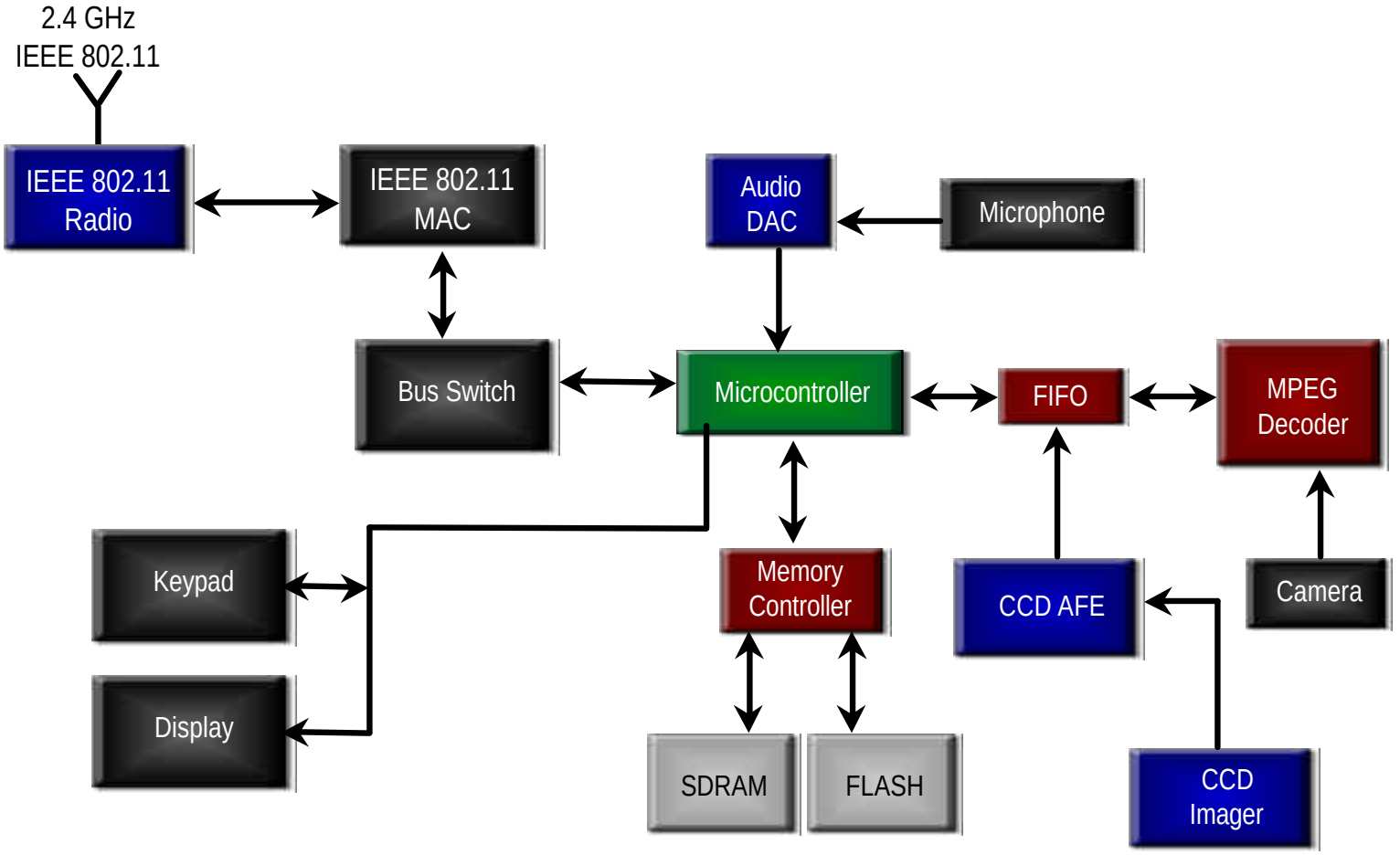
Gaming Console



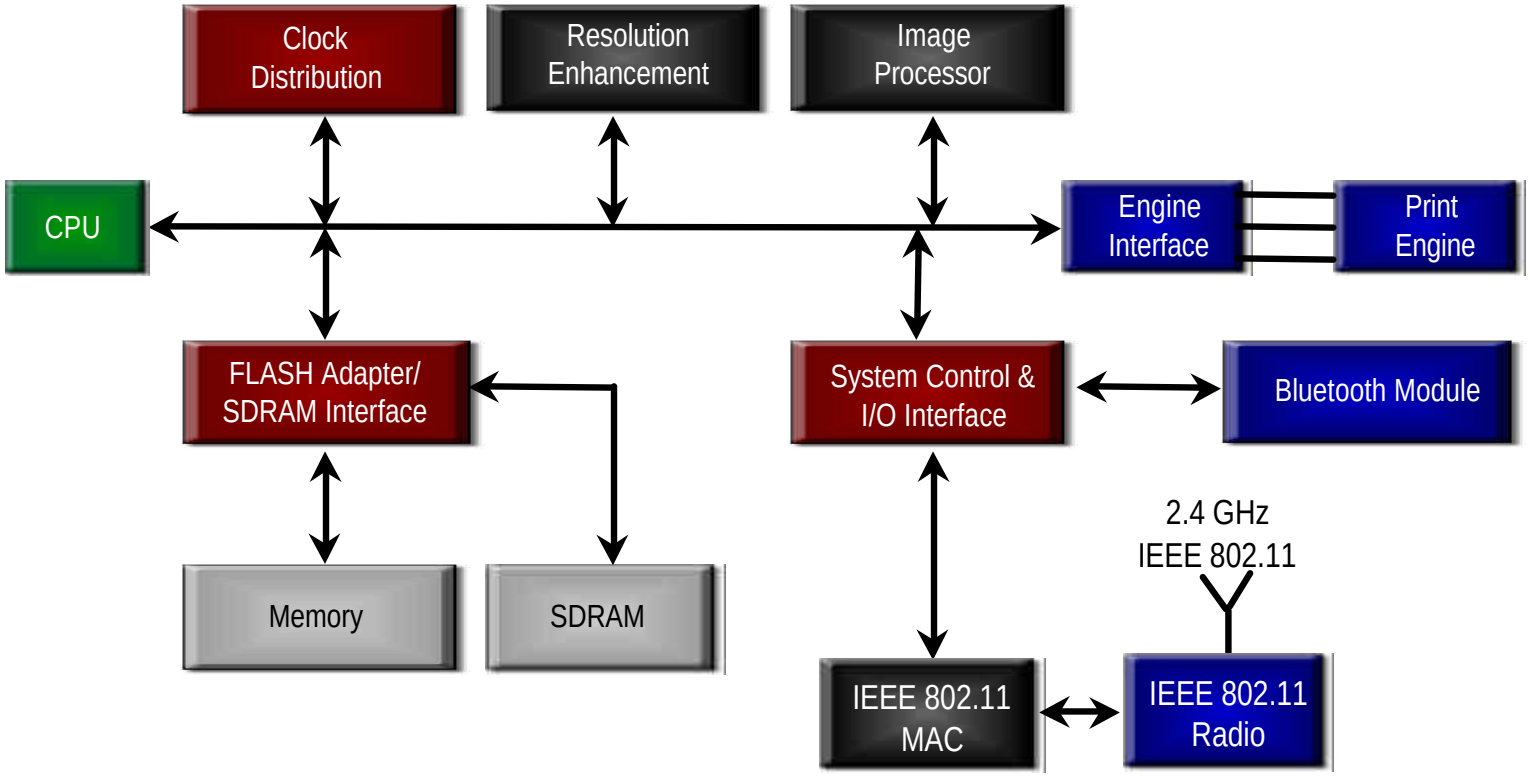
PC


Home Network
Bluetooth
Display
Graphics
HomePNA PHY
ISA
UART
Super I/O
CPU
LCD Controller
HomePNA MAC
USB
PCIISA
Audio
Speakers
Memory Controller
PCI
2.4 GHz IEEE 802.11
SDRAM
PCI to PCI Bridge
PCMCIA
Ethernet MAC
IEEE 802.11 MAC
IEEE 802.11 Radio
PCI
Ethernet PHY
Home Network
Modem
HDD
HDD Controller

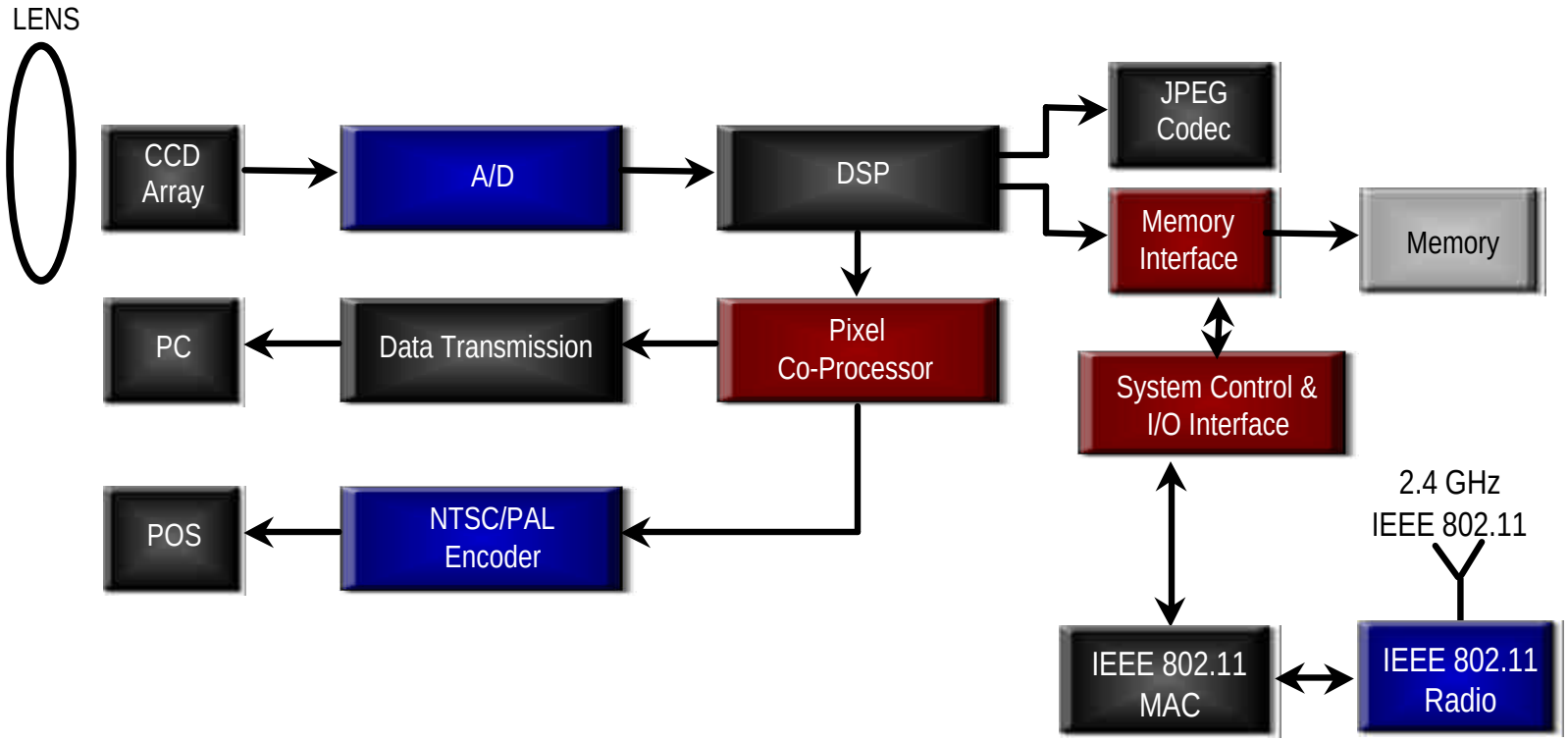
Home Security System



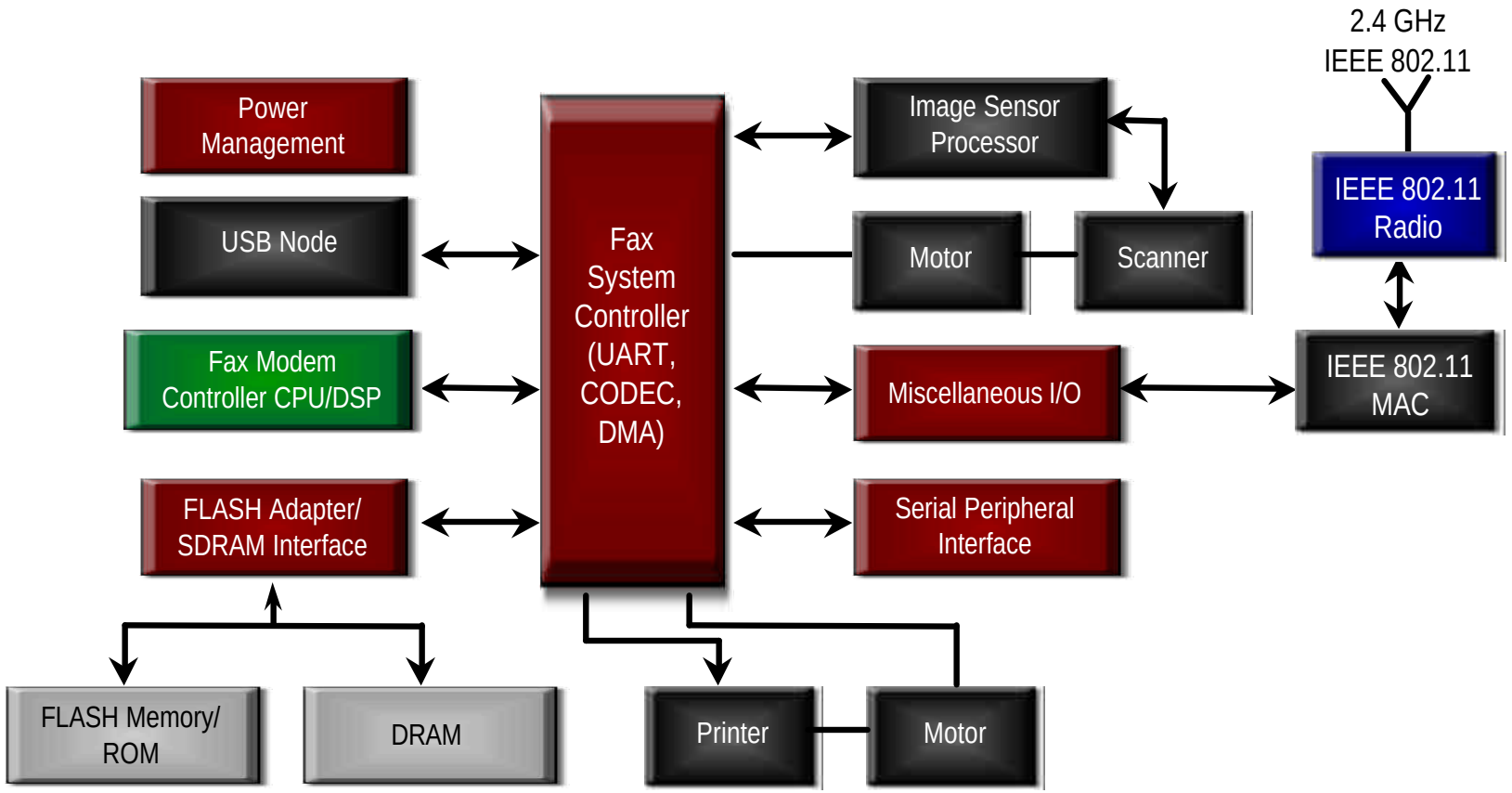
Printer


Clock Distribution
Resolution Enhancement
Image Processor
CPU
Engine Interface
Print Engine
FLASH Adapter/ SDRAM Interface
System Control & I/O Interface
Bluetooth Module
2.4 GHz
IEEE 802.11
Memory
SDRAM
IEEE 802.11 MAC
IEEE 802.11 Radio

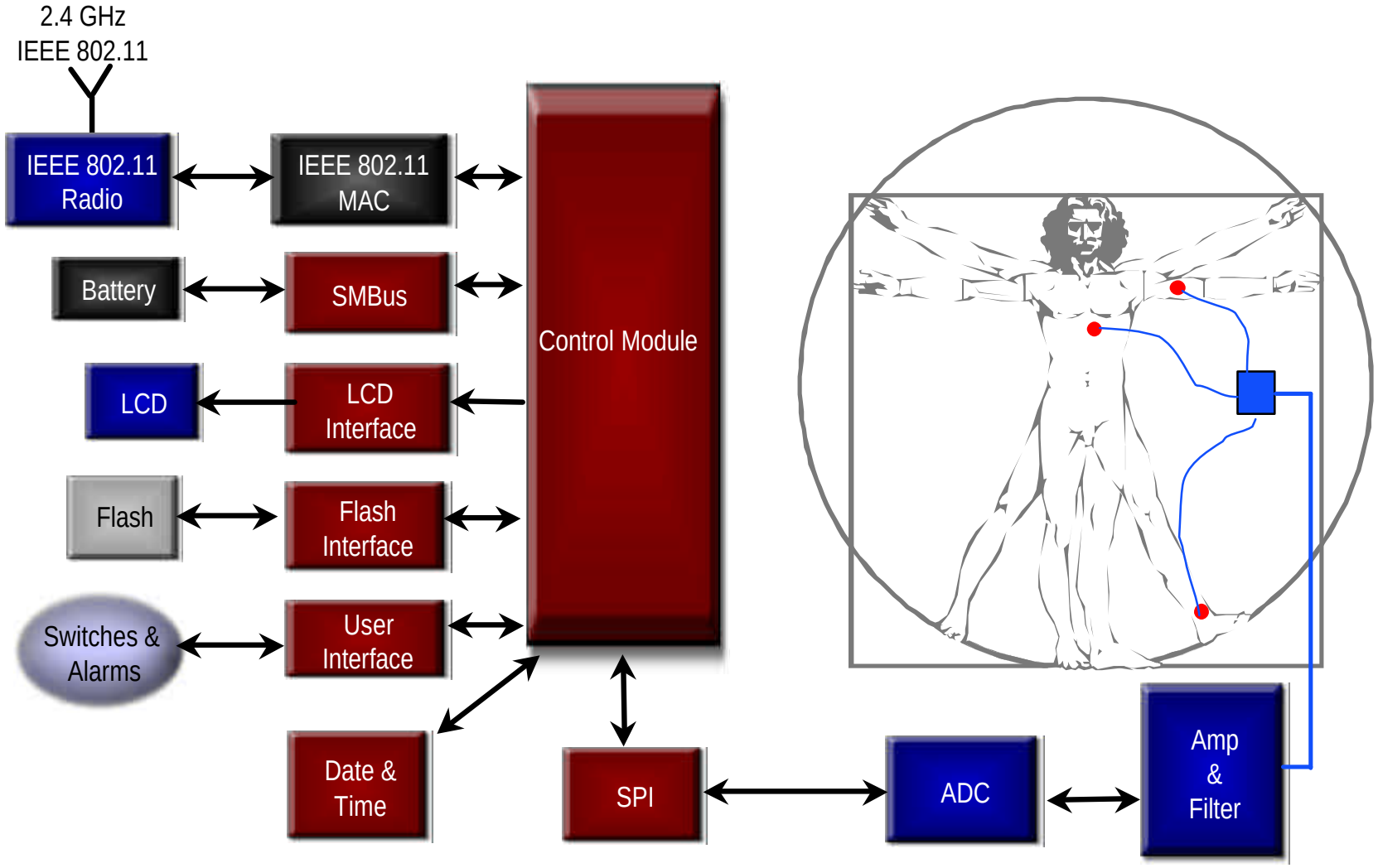
Scanner


LENS
CCD Array
A/D
DSP
JPEG Codec
Memory Interface
Memory
PC
Data Transmission
Pixel Co-Processor
System Control & I/O Interface
POS
NTSC/PAL Encoder
2.4 GHz IEEE 802.11
IEEE 802.11 MAC
IEEE 802.11 Radio

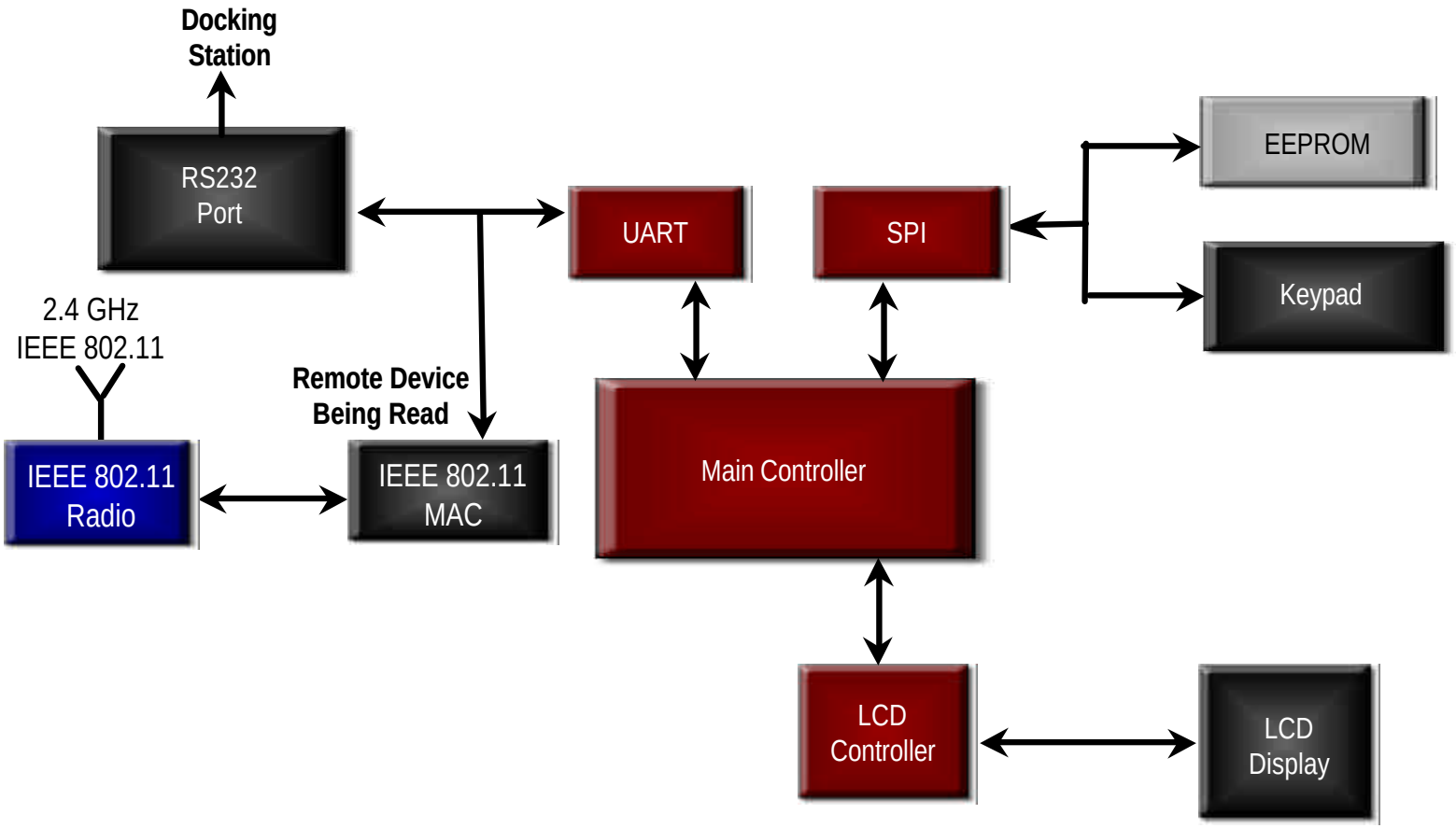
Multi-Function Peripheral



Wireless Patient Monitoring



RF Metering


Docking Station
RS232 Port
UART
SPI
EEPROM
Keypad
2.4 GHz IEEE 802.11
Remote Device Being Read
IEEE 802.11 Radio
IEEE 802.11 MAC
Main Controller
LCD Controller
LCD Display

Spartan-II Solutions for Wireless LANs-Based Products

- I/O control
  - Multiple front end interfaces
  - Multiple back end interfaces
- Hard disk drive interface
- Clock distribution
  - DLLs
- MPEG decoder
- Ethernet MAC
- Error correction
  - Reed-Solomon, Viterbi
- PCI
- Memory solutions
  - On-chip Distributed memory, BlockRAM
  - Memory controllers
- CPU / microcontroller
- HDLC controller
- ADPCM
- Color Space Converters
- Glue logic & system integration
  - LCD controllers, UARTs, DMA controllers

Advantages of Using Programmable Solutions

Xilinx Programmable Solutions Provide Several Benefits

- Time to market
  - Consumer devices require fast time-to-market
  - ASICs & ASSPs take 12-18 months to spin out
- Flexibility
  - Product customization to meet customer needs
  - Accommodate multiple standards & spec updates/changes
  - Feature upgrades
- Testing and verification
  - Re-programmable allows risk aversion
  - Your solutions are built on a proven FPGA technology with pre-verified silicon and IP that guarantees performance

Xilinx Programmable Solutions Provide Several Advantages

- Xilinx On-line - field upgradability
  - Remote update of software and hardware
  - Results in increased lifetime for a product (time-in-market) and allows new, interesting applications
  - Enable product features per end-user needs
- Issues in creating a stand-alone ASIC/ASSP
  - Choosing the right solution
  - Product customization
  - Development cost and amortization
- Low Cost

Lifecycle Component Logistics

- Xilinx is an assured source of supply
  - Spartan FPGAs are high volume standard parts
  - Xilinx is a Strategic customer to our fab partners
  - If a device is retired, designs are quickly portable
- Xilinx's solutions reduce exposure to component supply issues
  - Designs can be quickly adapted to efficiently address component supply problems
    - NAND to NOR type Flash support for example
  - Gives latitude in maintaining a cost effective BOM in dealing with the allocation, end of life & generational migration realities of today's component market

Specification Changes

- Emerging markets are exposed to multiple standards and specification changes
  - DSL Modem market
    - 6 different variations
  - DTV market
    - 18 different formats

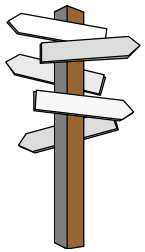
U.S. Networks Select Digital Broadcasting Format

ABC	720-Progressive. For non-HDTV broadcasts, ABC will use 480-line progressive format.
CBS	1,080-Interlaced. Wants to be compatible with HDTV sets as well as normal quality formats on regular analog television sets. Digital broadcasting will begin at select CBS-owned stations in the fall of 1998. By November 1999, CBS plans to be broadcasting digitally into 43% of U.S. households. For other broadcasts, CBS will use the 480-line Interlaced format.
NBC	1,080-Interlaced. NBC is leaning toward 480-line progressive for non-HDTV broadcasts.
FOX	720-Progressive. For non-HDTV broadcasts, Fox will use the 480-line progressive format.
PBS	For HDTV, PBS is undecided. For non-HDTV broadcasts, PBS will use the 480-line interlaced format.
Local Stations	Will have to conform to their network's format for national programming but can select any format for local programming.

Source: IC Insights

OEM/ Vendor

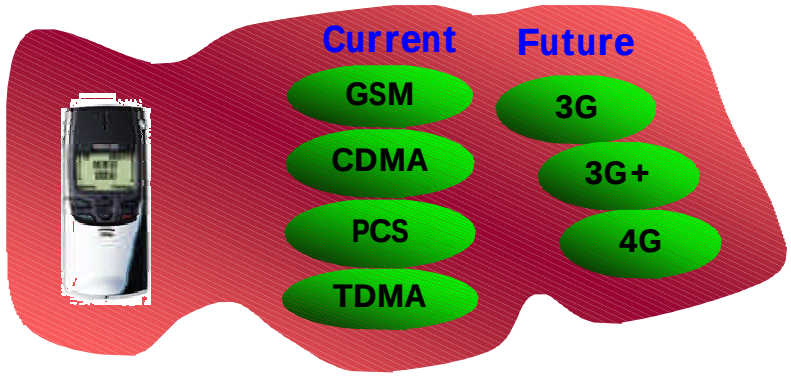
Market



A Programmable Solution Future Proof's Success

New Flexibility from FPGAs

Driving down the cost of consumer products with low cost reprogrammable products



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Enabling a whole new breed of consumer products

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Reprogrammable nature allows
- Field upgrades
- Field fixes
  - Mars probe repair from earth
- Support for numerous standards

Xilinx & Replay TV
- Revolutionizing consumer TV

FPGAs, the Unsung Hero

Driving the Consumer Digital Logic Revolution

- The digital consumer world is here
  - Imperatives driving market success
    - Time to market and time-in-market
    - Flexibility
    - Custom digital logic

- Xilinx - The answer for consumer digital applications
  - Introducing the low cost Spartan-II programmable family
    - Cost reduced for the consumer market
    - Fully programmable at the desktop, in the field or in the application
    - Future proofed for changing standards

Xilinx Digital Consumer Logic

A Natural Fit for Home Networking

- Xilinx solutions enable you to thrive in chaos
  - Fastest time-to-market
    - First to market, gains market share and revenue advantage
  - Xilinx Online provides reconfigurability in the field
    - Allows shipped product to support revisions to the spec
    - Enables unique opportunities to add Value
    - Increases life-cycle revenue yield & hence time-in-market
  - Enables rapid product proliferation
    - New designs can be quickly turned into derivatives
  - Feature superior lifecycle component logistics
  - Testing and Verification
    - Proven FPGA technology, software, test benches
- Cost Effective!!!

Agenda

- Introduction to wireless home networking
- Wireless LAN technology
- Consortiums
- IEEE 802.11
- HiperLAN & HiperLAN2
- Products & solutions available in the industry today
- Xilinx solutions in wireless LAN products
- Summary

Summary

- Wireless LANs are fast gaining popularity
  - High-speed wireless connectivity augmenting wired networks
  - Combine data connectivity with user mobility
  - Strong popularity in vertical markets such as academia, offices
  - Home networking
    - Telecommuters, sharing peripherals, sharing broadband access, desire for mobile connectivity in the homes
- IEEE 802.11 (a & b variations)
  - a - 5GHz standard, OFDM-based, data rates up to 40Mbps
  - b - 2.4GHz standard, Ethernet-based, data rates up to 11Mbps
- HiperLAN & HiperLAN2
  - 5GHz standard, OFDM -based, data rates up to 54Mbps

Summary

- Various wireless LAN products are being developed
  - Residential gateways with wireless LAN for home networking
    - Broadband access choices - DSL, cable, satellite, ISDN
  - Technology bridges (several choices)
    - IEEE 802.11-to-IEEE 1394, IEEE802.11-to-HomePNA, IEEE802.11-to-Ethernet, HiperLAN2-to-IEEE802.11, HiperLAN2-to-IEEE 1394, HiperLAN2-to-HomePNA, etc.
  - WLAN (HiperLAN2 & IEEE 802.11 a & b) enabled information appliances
    - Digital TV, DVD player, Internet screen phones, PCs, printers, scanners, etc.

Summary

- Xilinx solutions enable wireless LAN-based products
  - Spartan-II + IP provides a better solution than competing ASSPs
    - Higher performance & cost effective
    - Greater flexibility is provided through reprogrammability
      - The WLAN market is rapidly growing & the competition is rising products need to be rolled out - time-to-market
      - IRL provides time-in-market as specs for emerging technologies evolve
    - Features within the Spartan-II provide system integration
      - DLLs, SelectIO, BlockRAM
    - Embedded solutions
      - FPGA logic not used from IP can be programmed with other IP cores
    - Proprietary encryption algorithms can be programmed in the FPGA depending on the application and geography
  - Spartan-II FPGAs, CoolRunner & 9500 CPLDs provide system interconnectivity in wireless LAN based products